

FRUITING ORGANS FROM THE
MORRISON FORMATION OF
UTAH, U.S.A.

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FRUITING ORGANS FROM THE MORRISON FORMATION OF UTAH, U.S.A.

By M. E. J. CHANDLER

SYNOPSIS

This paper deals with a number of interesting plant remains from the Morrison Formation of Utah, U.S.A. Some are represented by numerous individuals, others by only one or a few. Three of the recorded genera (*Behuninia*, *Jensensispermum*, *Hillistrobus*) are new and five new species are described and figured.

With the exception of *Sequoia* all the plants appear to be extinct and are not comparable with any vegetation hitherto described; they differ from all Mesozoic plants previously known, not only in their characters but in their preservation as solid entities. Angiosperms appear to be absent in spite of superficial resemblances to them in a few cases.

The seed, *Jensensispermum redmondi* gen. et sp. n., is remarkable for a combination of characters which distinguish it from any recognizable family viz. a conspicuous embryo vesicle centrally placed in the massive endosperm, a complex chalazal structure partly embedded in endosperm and a cycad-like hilar cavity. The toadstool-like seeds of *Carpolithus radiatus* sp. n. have features in common with *Jensensispermum*. Both are of a type entirely unknown today.

The geology and mode of occurrence of the specimens are briefly outlined in a foreword by Mr. J. A. Jensen who regards the age of the parent deposit as probably late Jurassic. *Sequoia*, common in the Cretaceous and rare in the Jurassic, has no contribution to make on the question of age. The aspect of the flora is, however, essentially Mesozoic.

FOREWORD

By JAMES A. JENSEN, Curator

Geology Department, Brigham Young University, Provo, Utah, U.S.A.

Geology and Occurrence

THE material described herein was first discovered by Homer and Joanne Behunin of Redmond, Utah, and many of the specimens used in this study were donated by them. The interesting variety available from this locality is due to their patient diligence in collecting. Grateful acknowledgement is hereby made of their willing co-operation.

The material studied was collected from a single locality (east of Last Chance road leaving highway U10 near Fremont Junction) about five miles east of Willow Springs, Emery County, Utah.

Its geologic age is placed in the Brushy Basin member of the Morrison Formation (by Bennett (1955)).

The specimens occur as resistant casts of the original organic structures, such as seeds, cones, buds etc., and were found weathered out of a fine grained, grey, limey sandstone. Being simply casts of external surfaces, all internal structures so valuable to morphological studies are missing.

No leaves were evident in the matrix but other plant fragments of various kinds were abundant including wood sections ranging in size from small twigs up to pieces about 130 mm. in diameter and about 1.5 metres long. One area in the deposit contained numerous tuber-like objects which, owing to their concentration, appear to be at, or very near, their point of origin. Most of the material appears to have been subjected to disturbance during the process of fossilization.

Several large dinosaur bones were present but due to the activity of amateur bone collectors there is little evidence left to suggest the mode of their introduction into the area.

The presence of numerous freshwater Gastropods in an adjacent area and a large stream channel deposit in another, divided by the fossil plant deposit, suggests that the sedimentary environment consisted of a shallow pond, or lake, separated from a large stream by an elevated area.

The general region was one of flood-plain activity, so common in Morrison times, and was no doubt low in elevation. It was probably less than 300 metres above sea level although the present elevation is about 1650 metres. Moderate humidity and a warm climate are evident but conditions were far from those of a coal swamp.

The deposit is generally from 0.3 to 0.5 metres in depth and is somewhat resistant which results in its occurrence on the tops of two small hills. Modern erosion has removed the intervening area.

The discovery of several new genera and species of plants in these beds in central Utah is of great significance. They are very important to the study of Palaeoecology and may have some contribution to make to the problem of why dinosaurs were eventually unsuccessful in their environment.

The flora of the Jurassic period in the western United States has been described largely from formations other than those which contain the best fauna. Very little has been published about the varied plant forms of the Morrison formation (apart from Cycad stems) since conditions which preserved animal skeletons so well at that time were unfavourable for detailed plant preservation.

INTRODUCTION

The small group of plants here described has been entrusted to me by Mr. James A. Jensen of Brigham Young University, Provo, Utah, who with Mr. Behunin collected the bulk of the material. As I am wholly unacquainted with the formation, Mr. Jensen has also kindly contributed the foregoing account of the geology of the parent deposit and the mode of occurrence of the fossils. He and I are both indebted to Professor D. I. Axelrod for putting us in contact with one another and thereby making this investigation possible. I am personally indebted also to Professor T. M. Harris for sparing time to look at some of the more outstanding specimens. His opinion

on Mesozoic plants is worth infinitely more than my own. My experience of palaeobotany has been almost entirely restricted to the Tertiary. The sole justification, therefore, for attempting a study of these older fossils is that in their superficial appearance some of them bear a misleading resemblance to Angiosperms, while their preservation as solid entities, can be interpreted in the light of many years of research on similarly preserved Tertiary fruiting organs. The majority of Mesozoic compressions call for a different approach and a radically different technique. The best characterized and most abundant forms from Utah are not only entirely new to me but to Professor Harris also. They may, therefore, safely be assumed to be new genera and species the possible affinities of which are discussed in some detail in the systematic section which follows.

Despite the large quantities of specimens examined distinct forms are few, only seven species being sufficiently well characterized, having regard to the mode of preservation, for satisfactory or even partial determination or diagnosis. Among them is a species of *Sequoia*, not named specifically on account of its poor condition but showing on the surface of the cones typical *Sequoia* features. A detached small fragment of Conifer foliage may, or may not, belong to these cones but more probably to the species *Hillistrobus axelrodi* (see below). While *Sequoia* is a common Cretaceous genus in North America (Chaney 1951 : 188) it apparently occurs sparsely in the Jurassic elsewhere. Endo (1951 : 228 text-figs. 1, 2 ; with foreword by Chaney) described as *Sequoia jeholensis* a bifacial branchlet from the *Lycoptera* beds of Lingyuan, Jehol, in South Manchuria. These beds were stated to be of Upper or Middle Jurassic age. A cone of somewhat uncertain affinity was earlier recorded from the Upper Jurassic of the Boulogne area (Fliche & Zeiller 1904 : 787) under the name *Sequoia problematica*, but of it Endo writes (1951 : 230) " the relationship to *Sequoia* has not been demonstrated ". Hence while it may be possible for *Sequoia* to occur in Jurassic beds it should also be borne in mind that " the Morrison Formation is in the upper part of the Jurassic if not at its very top " while " the boundary of the Jurassic and Cretaceous in this part of the World [Utah] is a subject of some mild controversy " (Jensen, ex. lit., 18.2.64).

A second coniferous cone, represented by several specimens, may also belong to the Taxodiaceae. Professor Harris pointed out that there is some resemblance between these specimens and *Sphenolepis kurrianus* (Dunker) Schenk (Harris 1953 : 6, pls. 1, 2) but added that the limits of this species are ill-defined. Owing to the type of preservation of the Utah cones some of the diagnostic characters used in defining *Sphenolepis* and an allied genus *Elatides* Heer are not visible even if present. There is some reason to think that they could be male cones. Their external appearance is so distinctive that it seems justifiable to give them a name although their diagnosis is necessarily very incomplete. They are described as *Hillistrobus axelrodi*. This name is a tribute to Dr. A. J. Hill, the Dean of the College of Engineering (including Geology) at Brigham Young University. He and his wife have visited the site and have shown great interest in this work. The specific name *axelrodi* is after Professor D. I. Axelrod because of his part in introducing the writer to Mr. Jensen and to these plant remains.

Two other cones are too obscure for diagnosis but clearly different from the foregoing. They have therefore been illustrated and briefly described although no attempt has been made to name them.

There are only two other species which can be assigned, even approximately, to a systematic position and they, fortunately, are abundant. One of these, *Behuninia joannei* gen. et. sp. n. shows seeds borne on a dorsiventral sporophyll and may well belong to the Cycadales. The other, *Jensensispermum redmondi* gen. et. sp. n. is a peculiar albuminous seed whose foliage and mode of growth on the infructescence are both at present unknown. Although it shows some Cycadean features, for reasons to be discussed it cannot be placed in any recognized family. Its position must, therefore, be regarded as extremely doubtful but it is grouped provisionally with the Cycadophyta. The complex character of its chalaza excludes it from Cycadales and it is not possible to refer it to any family hitherto defined (cf. p. 154). The first of these two new genera is called after the initial discoverer of the plant material, Mr. H. Behunin and his wife Joanne. The fact that Mr. Behunin keeps a rock shop in the village of Redmond, Utah explains the specific name of the seeds described as *Jensensispermum* after James A. Jensen himself.

A fragment of a dorsiventral sporophyll with one broken partially embedded seed, although too imperfect for certain determination, has also been referred provisionally to Cycadophyta. The presence of Cycadaceous fruiting material in the Morrison is to be expected in view of the abundant Cycad stems long known to occur in Wyoming (Ward 1899: 521-958, pls. 57-172; 1900: 253-300; 1906: 179-203, pls. 46-63; Wieland 1906, 1916).

Two other plants are named *Carpolithus provoensis* and *Carpolithus* sp. (65, 66). With no knowledge whatsoever of their internal structure or organization it is impossible to form a sound opinion of their true affinity. These specimens are figured and described without any attempt to relate them to a Class or Family. Some figures by Andrews (1963: 927, 929, text-figs. 4-9, 15-19) of Lower and Upper Carboniferous Pteridosperm seeds and cupules suggest that they could be Pteridosperms or descendants of that group. Despite the fact that one of them bears a superficial resemblance to an Angiosperm berry, while *Jensensispermum* shows features which recall seeds of Sapindaceae, there are no grounds for regarding either as Angiosperms. In the latter case there are definite reasons for dissociating them from Sapindaceae.

Similarly unsatisfactory for determination are some peltate flattened circular heads with radial furrows and nerves. They are described and figured as *Carpolithus radiatus*. Certain of their seed characters suggest alliance with *Jensensispermum*. A large detached thorn cannot be placed. It is not even possible to say whether it has, or has not, any connection with one or other of the species seen. Evidence of its relationship is entirely lacking. This is also true of a few longitudinally ridged and furrowed elongate but obscure bodies with enlarged basal attachment (?) (Pl. II, figs. 135-145). There is nothing to indicate whether they belong to higher or lower plants but in the light of Andrews' figures of cupules, quoted above, a Pteridosperm ancestry is perhaps not excluded.

In addition to the above forms which may all belong to the higher plants, there are innumerable subglobular, irregularly shaped and sometimes flattened and sub-circular bodies with few distinctive features which could be Cryptogamous. Some of them show a clearly defined concentric structure, others a radial arrangement, others evidence of both, while many show form only and no structure whatsoever. In view of their ill-defined characters, although numerically important, only a few are figured and briefly described without naming or classification. Further discoveries may ultimately make it possible to determine their affinities. Meanwhile, it seems inadvisable to risk discrediting the work which is based on definite diagnostic features in other specimens by any attempt to classify these. Professor C. G. C. Chesters kindly examined a few of the better preserved examples but was unable to accept a suggestion that they might be fungi. Their association with masses of broken partly disintegrating wood to which in one or two cases they are attached (V. 51815-16) may indicate such an affinity but an algal relationship is equally possible. There the matter must rest for the present.

The quantities of wood fragments ranging from small twigs to branches several cms. in diameter of which about five hundred specimens have been seen is one of the striking features of these plant beds. Mr. Jensen writes also of large trunks which occur. Unfortunately there is no internal structure to help in the determination of most of this material and even the surface features are commonly ill-preserved. Some of the better fragments do however show a characteristic surface with numerous discontinuous sharp subparallel furrows like those described in *Behuninia* and *Carpolithus provoensis* (pp. 145, 162, Pl. 1, figs. 4, 5; Pl. 9, fig. 90). The furrows may indicate partially exposed fibro-vascular strands showing at the surface intermittently. Possibly their disposition is a family or group characteristic. Whatever the relationship the size of many of these fragments points to parent plants with the habit of shrubs or trees.

Although so little is known with certainty these fragmentary plants are of considerable importance. The fruiting organs are definitely new. The type of preservation is apparently unusual in the Jurassic. They can be removed, after weathering, from the matrix and examined "in the round". The crystalline preservation is responsible for the lack of detailed information. The original living organs were probably buried in quickly accumulated sediments which consolidated rapidly around them. Subsequently the organic entities appear to have decayed while calcium carbonate, silica or a mixture of both have infiltrated in solution into the hollow moulds and surrounding matrix. As the mineral crystallized out they reproduced the superficial features of the specimens from the impressions on the hollows. Thus the fossils would seem to be internal crystalline casts of external moulds of plant remains, whether fruiting organs of higher plants, wood, or Cryptogams. This explains the absence of organic structure especially inside the cast. When sectioned they are consistently crystalline throughout. There is no hint of mineral replacement of actual tissues cell by cell as in the Tertiary London Clay fruits and seeds. Even superficial cell impressions can scarcely be said to exist perhaps because the matrix was not fine enough to reproduce them faithfully on the

hollow moulds so that they could not be transferred to the surface of the casts. All that is normally shown are the macroscopic features visible on the exposed surfaces of the specimens when they were buried. When, therefore, a part or the whole of an outer integument or epidermis had been torn away or abraded prior to fossilization, fibres or other structures which would have been hidden in a perfect specimen were exposed superficially and are reproduced. Again a film of matrix penetrating along a crack or fracture in a specimen may have shown detail now reproduced in calcite or silica. Such a film could then afford a rare, ill-defined, glimpse of structures or organs otherwise completely unknown. It is perhaps under some such conditions that one now fractured cone of *Sequoia* appears to show obscurely the position and size of the seeds on the scales (Pl. 8, fig. 78). Normally, however, it is a useless and frustrating task to section these casts in the hope of revealing internal organic structures. There are no compressed coats or cuticles as in many Mesozoic plant remains, so that the wealth of detail available in such cases is lacking wholly in the Utah fossils. This factor of preservation means that important characters and coats in the fossils and the relation of these coats to one another cannot always be determined by direct observation but must be discovered by processes of induction. This of course adds to the difficulty of understanding the material. The distinctive macroscopic features in some of the species nevertheless make their study well worthwhile.

For determining the chemical composition of typical specimens thanks are due to the Mineralogical Department of the British Museum (Natural History). To the Director of the Royal Botanic Gardens, Kew, I owe the opportunity of examining in detail a number of Cycadaceous seeds both fresh and dried. Dr. K. I. M. Chesters has kindly typed the manuscript and has made valuable criticisms, Mr. G. Elliott has examined those specimens thought to be algae. The authorities of the Geological Department of the Brigham Young University, Provo, Utah have generously presented a large number of specimens to the British Museum (Natural History).

SYSTEMATIC DESCRIPTIONS

In the descriptions which follow, numbers in brackets refer to specimens which give evidence of special points described under each species. In every case the types have been returned to Utah. These and other specimens at Provo are indicated by arabic serial numbers without prefix. Those in the British Museum (Natural History) are indicated by a V. followed by the registered number.

The fragmentary character of the *Behuninia* sporophylls and the isolated condition of the seeds of *Jensensispermum* have made the interpretation of this obscure material rather difficult. Detailed comparison of as many specimens as possible has been essential. Only in this way could the diagnostic characters be detected, the connection between one specimen and another be established and a reconstruction from the detached remains be made. To illustrate adequately the features recognized by such methods it has been necessary to select a number of syntypes connected one with another by features in common. No single holotype in such material can provide adequate comprehensive evidence. For example differently abraded specimens

clearly linked by their major characters may show important successive coats or cavities which are not all visible in any one specimen. In the case of *Behuninia* a number of sporophyll fragments are needed to illustrate the difference between younger distally borne seeds (1, 2) and older ones (5, 6) which, having been more proximally situated, differ somewhat in appearance.

PLANT LIST

Group	Family	Genus and Species
Cycadophyta .	Cycadales .	<i>Behuninia joannei</i> gen. et sp. n. Genus ?
Cycadophyta ? .	Family ? .	<i>Jensensispermum redmondi</i> gen. et sp. n.
Gymnospermae		
Coniferales .	Taxodineae .	<i>Sequoia</i> sp.
	Taxodineae ? .	<i>Hillistrobus axelrodi</i> gen. et sp. n.
		Genera ?
Incertae Sedis .		<i>Carpolithus provoensis</i> sp. n. <i>Carpolithus radiatus</i> sp. n. <i>Carpolithus</i> spp. Unknown plant bodies or organs and much undetermined broken and partially shredded wood.

CYCADOPHYTA

Family CYCADALES

Genus *BEHUNINIA* nov.

DIAGNOSIS. Orthotropous albuminous seeds arranged in opposite or sub-opposite pairs on upper surface of dorsiventral sporophyll extending to distal extremity. Embryo-vesicles two, the more conspicuous terminal, the other lateral on upper surface below middle of seed.

TYPE SPECIES. *Behuninia joannei* gen. et sp. n.

Behuninia joannei gen. et sp. n.

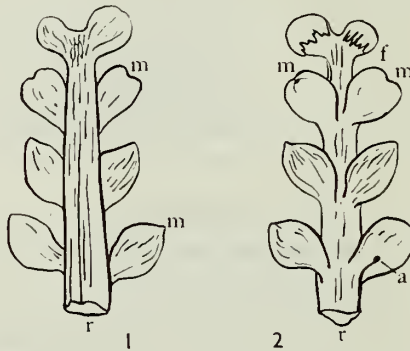
(Pls. 1-4, figs. 1-43; Text-figs. 1-12)

DIAGNOSIS. That of the genus.

SYNTYPES. Brigham Young University, Utah, Nos. 1, 2, 4, 5, 7-10.

DESCRIPTION. *Megasporophyll*. Dorsiventral (bifacial) bearing seeds in opposite or sub-opposite pairs extending to the tip. Seeds inclined at acute angles to the rachis arising on its upper surface and projecting laterally beyond its edges (4, 5, 19, V.51594) (Pls. 1, 2, figs. 4, 5, 9-14; Text-figs. 1-4). Those of each pair so closely adpressed to the rachis at their proximal ends that, when detached, they show a facet in the proximal half on the lower side (6, 9, 10, 15, V.51591) (Pls. 3, 4, figs. 22, 25, 35, 41; Text-figs. 5, 8, 11). Sometimes a narrow tract of sporophyll separates them along the middle of the rachis the upper surface of which shows a few sub-parallel discontinuous longitudinal furrows (1, 4). When viewed from below the

seeds are separated and their proximal ends are hidden by the prominent, broad, longitudinally ridged rachis itself (4, 5, 8). (Pls. 1, 2, figs. 5, 11, 14; Text-fig. 1). The distal end of the sporophylls may be incurved (? over abortive or young seeds) the free terminations being dissected (1) (Pl. 1, fig. 1; Text-fig. 2). On the lower surface between the seeds conspicuous, discontinuous, sub-parallel furrows indicate nerves, in places connected by transverse branches arising at wide angles, giving a reticulate appearance (1) (Pl. 1, fig. 2). A similar surface due to longitudinal furrows is also preserved on certain broken bits of wood (V.51596) and on the fruiting organ *Carpolithus provoensis*. In some specimens of *Behuninia* (14, 15) sporophyll fragments bearing seeds have a flattened bract-like aspect on the lower side which is enhanced by the tendency shown by their conspicuous nerves to fork acutely (Pls. 2, 3, figs. 16, 25; Text-fig. 4). The discontinuous character of the longitudinal

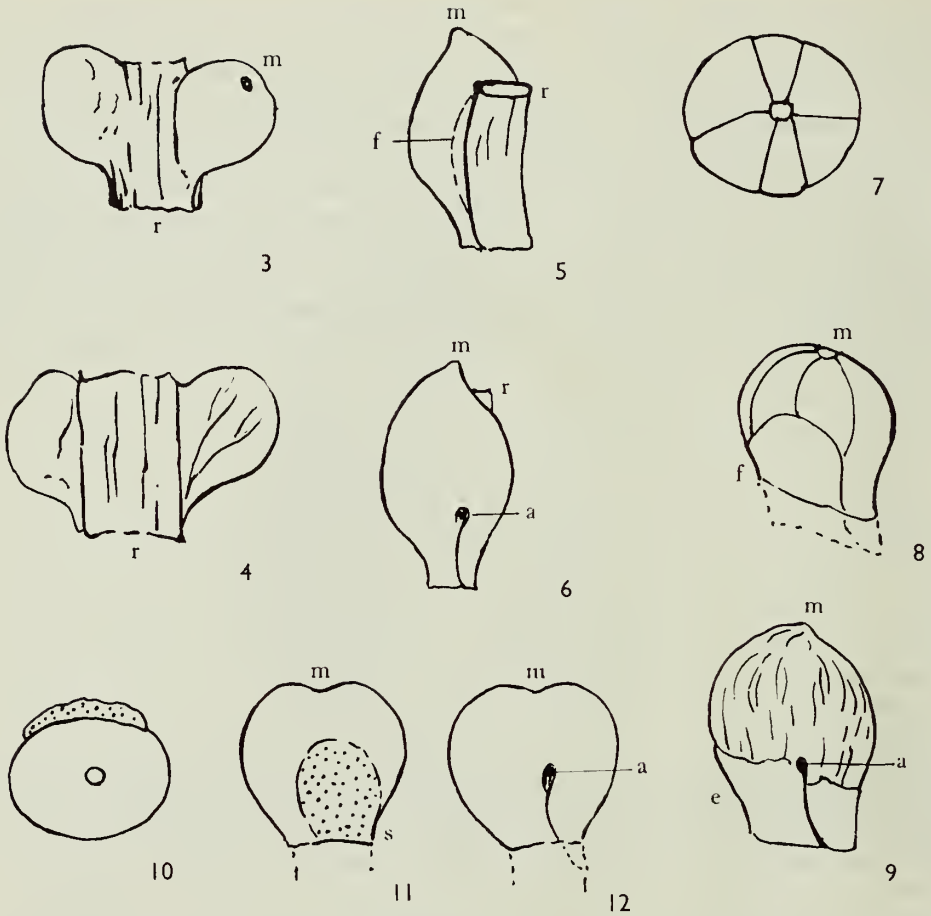


FIGS. 1, 2. *Behuninia joannei* gen. et. sp. n. (Reconstruction). Macrosporophyll with pairs of seeds arising from upper side of rachis. Fig. 1, Lower surface with prominent rachis. Fig. 2, Upper surface showing how seeds arise. *m*, micropyle of fertile embryo; *a*, micropyle of abortive (?) lateral embryo; *r*, rachis; *f*, fringed ends of incurved most distal segments of sporophyll.

nerves suggests that they are unevenly sunk in the tissues of the sporophyll and are exposed at the surface by some measure of abrasion of the original organic entities. One fragment (19) shows what looks like a narrow thickened rim (? projecting lamina flanking the rachis) (Pl. 4, fig. 37). Some seeds (13) and small twig fragments (V.51597) which probably belong here display bud-like structures of about four segments surrounding a central aperture. These may be immature seeds or ovules. Length and maximum breadth of sporophyll unknown. Breadth of fragments with paired seeds 20 to 25 mm. (largest specimens preserved). Maximum breadth preserved of rachis about 5 to 7 mm. narrowing towards the distal end.

Seed. Varying somewhat in shape and size according to its position on the sporophyll. Younger distally placed seeds tend to be smaller and subglobular (1, 2, 3, V.51588). Older seeds are more elongate, obovoid or sub-pyriform when the integument is preserved, but usually show some measure of dorsiventral compression

(4, 5, 19). Unabraded seeds are often pointed distally. One or two large much inflated subglobular seeds, 15 or 16 mm. long and broad (7, V.51595) are not quite complete at the proximal end. A few of the larger seeds, not necessarily fully mature since they appear to have been soft and crushable, are more attenuated at the proximal end (17, 18). Possibly they grew further down the sporophyll and projected more conspicuously beyond its edges. Such seeds (Pl. 3, figs. 30-33) are smooth externally as if less abraded than the more rugose specimens to be described (Pl. 2, figs. 17, 18; Text-fig. 9). One of the smooth seeds (17) shows the micropyle as a transverse slit (Pl. 3, fig. 31). Another (18) gives an appearance of two closely adjacent pores of which the significance is not clear. Seeds which had been abraded before fossilization so that all trace of pulp was removed show the micropyle very clearly. Thus a smooth inflated well developed specimen (10) (Pl. 3, figs. 21, 22; Text-figs. 7, 8) has a sharply defined circular scar against which clearly marked straight unbranched longitudinal nerves terminate. These nerves arise at the base of the seed on the upper surface. On the lower they can be traced upwards from the margin of the basilateral facet. The rigid smooth appearance in this case suggests that a hard inner layer of the integument is exposed. A similar circular micropyle to which regularly spaced unbranched fibres converge over the external surface of the hard layer occurs in the living *Macrozamia douglasii* Hill from Queensland. In *Stangeria eriopus* (Kunze) there are straight longitudinal fibres from base to apex at the same level in the integument. Some of the fossil seeds are mineral replicas of endosperm which must have been exposed either by splitting of the integument or by a greater measure of abrasion (Pls. 2, 3, figs. 10-12, 23; Text-figs. 3, 4, 10-12). Upon the rounded end of this "endosperm" the terminal micropyle, marking the outer end of a fertile embryo-vesicle, is indicated by a deep circular depression (8, V.51593). A similar but slightly less conspicuous lateral depression on the upper surface just below the middle is seen on a few seeds and appears to indicate a second, perhaps abortive, embryo-vesicle. This is suggested by analogy with *Cycas revoluta* Linn. The position of this second vesicle appears to be constant in the fossil. Although best exposed on the endosperm replica it is visible in some instances on specimens with some of the integument preserved (9, V. 59591)(Pls. 2, 3, figs. 17, 18, 34; Text-figs. 6, 9) perhaps owing to drying, contraction and clinging of the closely adherent integument. The lateral vesicle is connected by a narrow clearly marked furrow with the proximal end of the seed (9, 20, V.51591) (Pls. 2, 3, figs. 18, 34; Text-figs. 6, 9, 12). The seeds are albuminous, orthotropous. Micropyle terminal, attachment basal. Nervation and rugosities of the surface normally longitudinally aligned but nerves on the lower surface may fork as described above. Some specimens show exceptionally well both the longitudinal simple nerves on the upper surface and the forked nerves on the lower surface (Pls. 3, 4, figs. 25, 41-43). Other specimens appear to have undergone further abrasion and dessication before fossilization. These show irregular longitudinal rugosities such as could be caused by repeated splitting on drying of thin pulpy tissues like those of Cycads. One seed (9) (Pl. 2, figs. 17, 18) shows the exposed pulp still covered at the base by part of an outer epidermal layer. All seeds show some evidence of the apical micropyle although



FIGS. 3-12. *Behunia joannei* gen. et. sp. n. Figs. 3, 4. Pair of seeds attached to fragment of rachis. Fig. 3, Upper surface. Right hand seed, cast of endosperm with apical micropyle exposed by abrasion of testa. Fig. 4, Lower surface with longitudinally ridged rachis and branching nervation on one seed. Figs. 5, 6. Young seed still attached to rachis. Fig. 5, Lower surface. Fig. 6, Upper surface showing lateral depression, ? micropyle of abortive embryo, from which a distinct furrow passes to proximal end of seed. Figs. 7, 8. Detached seed with outer layers of testa abraded exposing simple fibres converging to micropyle on innermost layer. Fig. 7, Apex. Fig. 8, Lower surface with facet produced by pressure against rachis. Fig. 9, Seed with epidermis abraded above where irregular longitudinal ridges of contracted flesh are shown. Micropyle of abortive embryo and associated furrow seen below. Figs. 10-12. Internal cast of seed (= endosperm). Fig. 10, Apex with micropyle. Fig. 11, Lower surface with facet as in Fig. 8. Fig. 12, Upper surface with micropyle of abortive embryo as in figs. 6 and 9. *a*, abortive lateral embryo; *e*, remaining epidermis; *f*, facet; *m*, apical micropyle of fertile embryo; *r*, rachis; *s*, adherent matrix over the facet.

sometimes indicated only by the convergence of nerves or other tissues but sometimes by a visible aperture. It is by analogy with Cycadales that this has been interpreted as the micropyle. The basilateral furrow has a very slight sigmoidal curvature and separates a narrow, scarcely reflexed snout-like region on the outer side of the seed from a somewhat broader region nearer to the rachis. It could mark a rudimentary device for splitting the integument below the second embryo (9, 14, 20, V.51592) (Pl. 3, figs. 26-28, 34; Text-figs. 6, 9, 12). The snout-like region can be detected in many specimens even when the second embryo-vesicle is not exposed or reproduced on the cast. Distal seeds about 10 mm. long, 6.5 mm. in transverse diameter. Proximal seeds about 16 mm. long, 12 to 16 mm. in maximum diameter. These dimensions undoubtedly fall short of a maximum which would have been associated with the proximal end of the sporophyll but are the largest yet encountered.

REMARKS. About seventy specimens including twenty with paired seeds still attached have been examined but foliage, male organs and *complete* female sporophylls are quite unknown. These last are always represented by short lengths with one or a pair of seeds attached so there is nothing to indicate their size when complete. By examining the extant fragments side by side it has been possible to reconstruct the form at least of their distal ends. There are also isolated detached seeds. Occasionally the two seeds of an attached pair are unequally developed. The pressure facets well exposed on detached fruits sometimes lie on the opposite side to the lateral embryo-vesicle, in part at least, but are sometimes in a plane at right angles to it.

The dorsiventral sporophyll with paired seeds arising from its upper surface suggests affinity with Cycadales of the *Cycas* type. With such a relationship Professor Harris expresses agreement and he has pointed out that the presence of seeds right to the tip of the sporophyll indicates a distinct type of Cycad. Further support for Cycadalean relationship is afforded by the orthotropous albuminous seed with terminal micropyle, longitudinal fibres as described and integument which may be fleshy in part. The fossil also differs from Recent genera in the apparently uniform position of the second lateral embryo-vesicle. It has therefore been necessary to institute a new generic name. It and the specific name are explained on p. 142. The broken condition of the elongate sporophyll accords with that of the wood so abundantly represented in the deposit. It is undoubtedly connected with the mode of accumulation of this plant débris.

Genus ?

(Pl. 4, figs. 44-46; Text-fig. 13)

DESCRIPTION. *Macrosporophyll*. Represented by a fragment of a dorsiventral thickened scale perhaps one lobe of a pair. A crenature probably directed towards the axis of a cone as in *Zamia* or *Ceratostigma* retains the remains of a seed seated within it. The distal end of the seed is missing. A possible reconstruction of the scale is shown in Text-fig. 13 where the unbroken lines show the specimen as it now appears, the broken lines the parts missing. The edge of the crenature forms a low rim conspicuously shallower on one surface than on the other (Pl. 4, figs. 44, 45) so as

to expose the margin of the seed lying in the hollow. Laterally the crenature is prolonged into projecting "claws" which help to grip the seed. The claw regarded as the outer one is shorter, bluntly rounded, more or less complete. The inner claw is broken so its true length is unknown (cf. Text-fig. 13). Surface of sporophyll rough as if much abraded but on the less shallow side of the crenature a few slight furrows are visible at right angles to the edge (Pl. 4, fig. 44). Breadth of broken edge of sporophyll about 11 by 8 mm., the maximum dimension lying parallel with the broad surface.

Seed. Broken transversely so that its complete length cannot be ascertained. The subelliptical section (Pl. 4, fig. 46) indicates a somewhat greater degree of inflation where it abuts on the shallower edge of the crenature and a less convex surface on the opposite side. The proximal part of the seed which remains suggests that it was

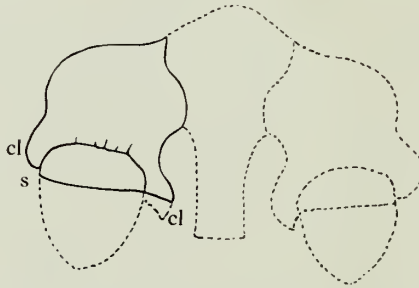


FIG. 13. Cycadales? Genus? Fragment of a dorsiventral thickened scale probably one lobe of a pair. Reconstruction as explained on p. 149. Broken lines represent missing parts. *s*, seed; *cl*, claw-like prolongations of crenature which holds seed.

ovoid, with marginal angle having a narrow flattened marginal rim on the more inflated surface. On this surface there is an appreciable space between seed and crenature suggesting that pulpy tissues of the integument have been destroyed leaving exposed the hard bony layer. A similar space also exists on the less inflated surface of the seed but is there less obvious. The transverse section now exposed also indicates a shallow marginal furrow on the outer edge of the seed where it abuts on the outer claw of the crenature like the furrow sometimes seen in species of *Cycas*. The persistent hard integument varies in thickness from 1 to 2 mm. It is thickest where adjacent to the broken inner claw. Although the surface of the hard integument is so worn there are obscure indications of one or two longitudinal fibres on the less inflated side. Maximum breadth of seed parallel with the broad surface of the sporophyll, 14 mm.; breadth at right angles to this surface, 12 mm. Length of fruit preserved above rim of crenature, 8 mm. on the more inflated side, 5 mm. on the opposite side.

AFFINITIES. The manner in which the seed is partly embedded in the sporophyll and the dorsiventral structure suggest a possible affinity with such Cycadales as *Zamia* or *Ceratostigma*. The form of the apex of the sporophyll is not known. The

reconstruction in Text-fig. 13 is not therefore intended as a portrait but serves to show that a Cycad-like structure is not impossible for the fragment which alone remains. In view of the scanty imperfect evidence the reference to Cycadales must be tentative only and no generic diagnosis can be based on this solitary fragment.

CYCADOPHYTA ?

Family ?

Genus *JENSENSISPERMUM* nov.

DIAGNOSIS. Infructescence and fruit (if any) unknown. Seeds subovoid to subglobular, germinating by splitting at micropylar end. Integument probably pulpy. Funicle passing from hilum to chalaza through shallow hilar cavity. Hilar scar at inner end of cavity, large, gibbous, at right angles to longer axis of seed. Chalaza large, occupying approximately half of the seed connected at one end with hilar scar, penetrating into endosperm but later retracting and releasing it. Endosperm occupying other half of seed, turgid, at first hemispherical, later sometimes becoming conical by contraction, bearing a median navel-like embryo-scar.

TYPE SPECIES. *Jensensispermum redmondi* gen. et sp. n.

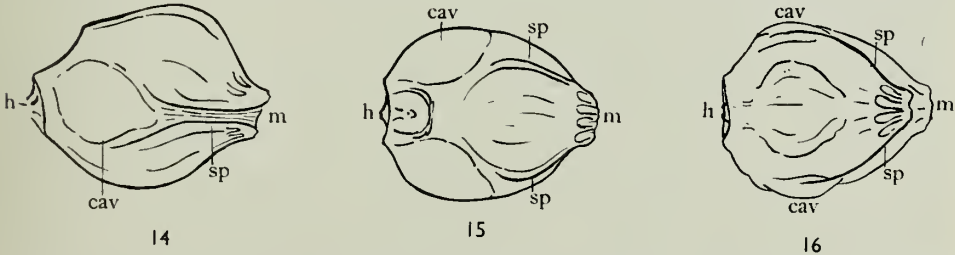
Jensensispermum redmondi gen. et sp. n.

(Pls. 5-7, figs. 47-74 ; Text-figs. 14-28)

DIAGNOSIS. That of the genus.

SYNTYPES. Brigham Young University, Utah, Nos. 22-30.

DESCRIPTION. *Seed*. Subovoid when integument is preserved, pointed at micropyle (22, 23) which in some seeds is terminal on the longer axis opposite the hilum (22, 23) (Pl. 5, figs. 47, 51 ; Text-fig. 17) and in others terminal on the shorter axis (24) (V.51600 ; Text-figs. 18, 19). The position varies with the shape of the seed. The variations may perhaps be related to situation on an unknown inflorescence.

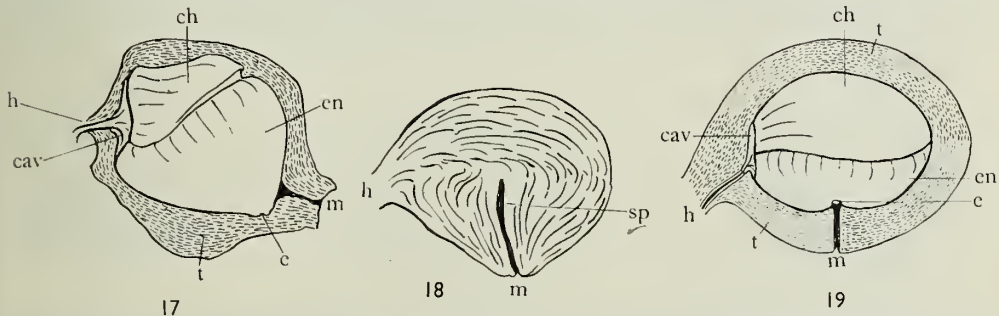


FIGS. 14-16. *Jensensispermum redmondi* gen. et sp. n. Fig. 14. Specimen interpreted as seed with integument preserved, side. In this specimen micropyle is opposite hilum (based on 22). Fig. 15. Same, from chalazal side. Fig. 16. Same, from side with endosperm. *cav*, shallow superficial cavities now occupied by mineral casts, exposed by abrasion of epidermis ; *h*, hilum ; *m*, micropyle ; *sp*, plane of weakness perhaps connected with germination.

Seeds tend to split transversely at the micropyle perhaps in connection with germination (23, V.51599) (Pl. 5, figs. 51, 52; Text-figs. 14, 18). One which may be a virtually perfect seed shows a pair of shallow superficial lateral cavities now occupied by mineral casts (22) (Text-figs. 14-16). The smooth well-defined surface of these casts indicates that the cavities were originally closed superficially so the former presence of an epidermis may be inferred. In many specimens remains of an inner pulpy layer of the integument have been exposed. The integument has become dried and shredded as in *Behuninia* (p. 147) and therefore appears rugose and somewhat fibrous in fossilization, the orientation of the ridges or fibres being from hilum to micropyle (23) (Pl. 5, fig. 51; Text-fig. 18). Such tissues must originally have covered the whole seed as they are seen on both sides (23) (Text-fig. 18) and when most complete they conceal the internal hilar scar. At the hilar end there is a small cavity. It is very shallow at right angles to the length of the seed and is traversed by the funicular fibres in their passage from the external hilum to the seed-cavity proper (Text-figs. 17, 19). Its existence is demonstrated by its internal cast in some specimens (28, V.51600) (Pls. 6, 7, figs. 62, 63, 74; Text-figs. 17, 19-22). It varies somewhat in size and form and at first sight suggests a slightly thickened hilar scar until its true nature as the mineral cast of a hilar cavity is understood.

The most frequent and conspicuous entity preserved is the subvoid internal cast of the seed-cavity itself. This is truncate at the hilar end by a large, gibbous, sunk scar at right angles to the longer axis of the seed. It marks the inner limit of the hilar cavity and is referred to above as the internal hilar scar. It is exposed when the cast of the hilar cavity is missing as is often the case (25) (Pl. 6, fig. 58; Text-figs. 23-25). The hilar scar may show apertures where the fibres of the funicle penetrated. Some are visible along the straight margin passing to the front part of the endosperm. Others are seen at the centre of the scar (25) (Pl. 6, fig. 58; Text-fig. 23). The seed-cast is divided along its major axis into two regions; the endosperm and the chalazal area. The endosperm is adjacent to the straight edge of the gibbous hilar scar and is commonly hemispherical (Pl. 6, figs. 56, 57, 61; Text-figs. 20, 21, 24, 25) more rarely hemipyramidal and narrowed towards the hilum (24, V.51606). It normally has a smooth distended surface but in some specimens is puckered and somewhat contracted and conical as if it had begun to dry out (26, V.51613). It always bears a conspicuous, small navel-like circular scar sunk in a shallow median depression. As the integument is so often abraded the scar is a conspicuous feature. When it is best preserved it has a convex round centre like a pin-head (25, 30, 31, V.51601, V.51603) (Pls. 5-7, figs. 53, 56, 57, 61, 71, 72; Text-fig. 24). Occasionally the "pin-head" is partially or wholly extruded. By analogy with many Recent plants, more especially Cycadales and Palmae, this scar marks the point where the micropylar canal impinges on the endosperm. Such scars in Recent seeds indicate the presence of a superficial embryo-vesicle sunk in the endosperm and are here called the embryo-scar. Where the pulpy integument is partially preserved the embryo-scar may be concealed, but its position in such cases is indicated, as already noted, by the convergence towards it of the fibrous-looking pulp. The endosperm is very sharply delimited from the chalazal area (25, V.51600) (Pls. 5, 6, figs. 55, 62, 73; Text-figs.

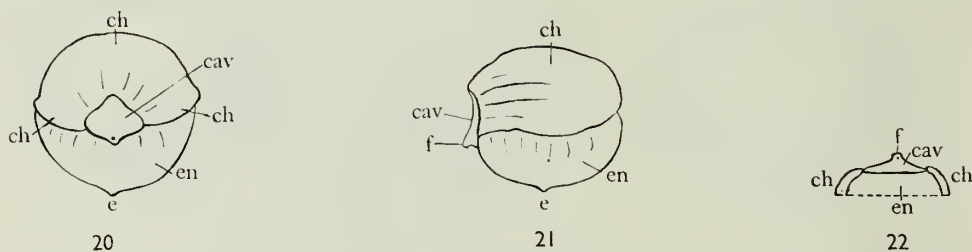
21, 23, 25) from whose margin striations due to fine lines of contraction, but also fine nerves diverge onto its surface. The nerves can be detected for a short distance only (29) (Pl. 7, fig. 68) and are best exposed when most of the chalazal area is missing. The endosperm evidently arises from and is firmly attached to the chalazal area which abuts upon the gibbous part of the hilar scar (Pl. 6, fig. 58; Text-fig. 23). In the less abraded seeds the area may be very thick (35). It commonly appears to overlap onto the endosperm and partly embrace it. It lies, of course, opposite to the micropyle. When present, the cast of the hilar-cavity slightly overlaps both halves of the seed (Text-figs. 17, 19, 20). In a few better preserved specimens the surface



FIGS. 17-19. *Jensensispermum redmondi* gen. et sp. n. Fig. 17. Seed as in Text-fig. 14 with micropyle opposite hilum depicted with pulpy integument removed on near side so as to expose internal cast. In this seed endosperm has become conical with embryo at point of cone. The chalazal area is somewhat shrunk and retracted. Integument reconstructed. Fig. 18. Seed with downward directed micropyle. Epidermis abraded exposing shredded dried pulpy integument. Fig. 19. Seed of similar shape to 18 but with pulp removed on near side as in 17. The endosperm is smoothly rounded and chalazal area unshrunk (integument reconstructed). *cav*, cavity at hilar end represented by a calcite cast through which funicle passes to inner side of hilar scar and chalazal area, *ch*. *e*, embryo scar in endosperm, *en*. *h*, hilar region; *m*, micropyle; *sp*, plane of splitting; *t*, pulpy integument.

of the chalaza which lay in contact with the integument is smoothly finished and traversed by distinct separate longitudinal nerves arising at the edge of the hilar scar or from beneath the cast of the hilar cavity (28, V.51610). The nerves sometimes show branching and anastomosing producing raised areas, obscurely seen between the reticulations thus formed. More often, the smooth surface has been worn away exposing irregular rugose tissues (Pls. 6, 7, figs. 66, 70; Text-fig. 26). In many seeds the smooth surface is concealed by remains of the pulpy integument. Owing to different degrees of abrasion the chalazal area varies much in size relative to the endosperm. At its largest it occupies half to rather more than half of the total surface of the seed-cast. In other specimens it is proportionately reduced or it may be almost entirely worn away. Some (?) riper seeds show it retracted from the endosperm and in these it is much smaller, puckered or concentrically wrinkled, with its free margin thickened and raised (26) (Pl. 6, fig. 64; Text-fig. 17). It is in these last that the endosperm tends to be conical and contracted with the embryo-scar at the point of the cone. In a few specimens the endosperm appears to have been

released from the chalaza and its rear surface, thereby exposed, may be concave with adherent patches of tissue at the centre of the concavity only where the two halves were most intimately fused. The nerves are then seen radiating from the sharply defined margin of the concavity onto the endosperm. The patches of tissue described sometimes form a knob-like projection like the "shank" of a button represented by the endosperm itself (27, V.51602) (Pl. 7, figs. 69, 70 ; Text-figs. 27, 28). In some seeds that are detached from the chalaza the rear surface of the endosperm appears longitudinally puckered. Some specimens have the endosperm corroded but these can be recognized by the remains of the embryo vesicle which persists surrounded by a mere frill of endosperm when most of the rest of the seed has been destroyed.



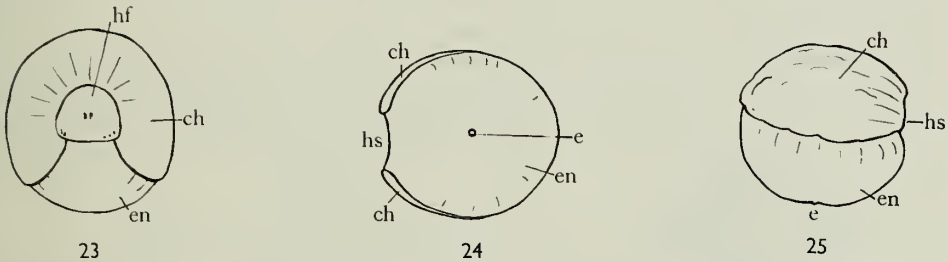
FIGS. 20-22. *Jensensispermum redmondi* gen. et sp. n. Fig. 20. Internal cast of seed, hilar end with cast of small hilar cavity showing aperture for funicle near margin contiguous with endosperm. Fig. 21. Same, side. Cast of hilar cavity on left. Endosperm occupies lower half of figure. Chalazal region in upper half. Fig. 22. Same (hilar end only drawn), looking onto endosperm. Cast of small hilar cavity pierced by funicular aperture again seen and flanking margins of chalazal region. Chalazal region, *ch.* *cav*, hilar cavity (cast) with funicular aperture, *f.* *en*, endosperm ; *e*, embryo-scar.

The grounds for describing the rougher half of the seed as chalaza are the manner in which the endosperm is related to it and fused with it, the mode in which nerves on the inner margin of the endosperm are derived from it and its relationship to the hilar cavity and internal hilar scar. A chalazal region of this type is found in many palm seeds where the actual hilum is situated at one end of a large thick chalaza parallel with the longer axis of the seed and penetrating deeply into the endosperm. In such palm seeds when the chalazal tissues are removed by maceration, the endosperm shows a marked concavity where the two were fused, a few nerves may diverge from the area of fusion and the surface is fluted or slightly corrugated around the rim of the concavity. Although for the sake of clarity *Palmae* have been used to help elucidate and explain the structure of *Jensensispermum* no relationship to *Palmae* is thereby implied. In *Cycads*, on the contrary, the chalaza scar is simple circular and thin immediately overlying the hilum and hilar cavity.

Diameter of seeds measured at right angles to the hilar scar ; 6 to 10 mm. Maximum diameter through embryo scar and chalaza : 5 to 9 mm. Maximum diameter at right angles to the preceding : 5 to 9 mm.

REMARKS. About three hundred specimens the majority so abraded as to show

little but the internal seed-cast, with or without remains of an integument. It is always difficult to understand, interpret, and describe any specimen which has no living counterpart. The difficulties can sometimes be resolved, as in the present instance, by taking account of comparable structures in living, even if unrelated, forms. In such a comparative use of living material, it is of the utmost importance to pay due regard to the mode of preservation of the fossil so that the structures seen may be correctly interpreted, otherwise the comparison can be very misleading. In order to explain the structure of this unique plant it has been necessary to write an informal and discursive description, incorporating matter usually reserved for Remarks at the end of a more formal account. Such a departure from normal precedent was needed to justify the interpretation placed upon the organs described.



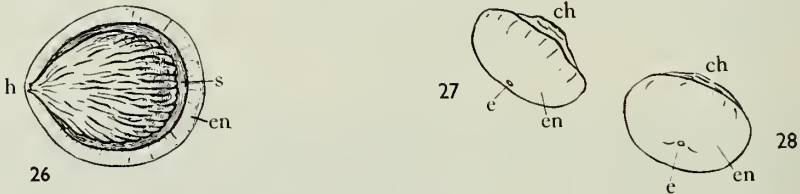
FIGS. 23-25. *Jensensispermum redmondi* gen. et sp. n. Fig. 23. Internal cast of a seed with smoothly rounded endosperm. Hilar end with concave scar which forms the inner surface of the hilar cavity. Apertures for funicular fibres are indicated. Fig. 24. Same, surface of endosperm partially embraced by edges of chalazal region. Inner surface of cavity in profile on left. Fig. 25. Same, lateral aspect with hilar scar on right. Chalazal region above; endosperm below. *ch*, chalazal region; *e*, embryo scar; *en*, endosperm; *hs*, concave scar of hilum in profile; *hf*, hilar scar (inner surface).

A proper understanding of the endosperm is fundamental to the understanding of the seeds and this has already been dealt with at some length. The significance of the hilar cavity reached on theoretical grounds is borne out by dissections of fresh seeds of *Encephalartos villosus* Lem. where a comparable shallow cavity is traversed by funicle fibres in their passage to the circular superficial thin chalaza scar at the proximal end of the endosperm. Bearing the above structures in mind the position of the hilar cavity in the fossil in relation to the rest of the seed inevitably indicates the former presence of an integument which entirely covered the whole: endosperm, chalazal region and hilar cavity. Although in many specimens it has largely disappeared its remains have been detected. The evidence of an integument which was probably pulpy and its tendency to split near the micropyle thereby producing an appearance of two "jaws" serves to connect the less abraded seeds with one almost perfect specimen (22) (Pl. 5, figs. 47-49; Text-figs. 14-16).

The systematic position of these fossils, named *Jensensispermum redmondi* for reasons given on p. 142, cannot yet be regarded as satisfactorily established. Nothing is known of the way the seeds were borne on an infructescence or axis, nor is there anything to show whether they were, or were not, enclosed in any kind of fruit or

“cupule”. While the pulpy integument, endosperm with superficial embryo-scar and hilar cavity accord with corresponding structures in Cycadales, *Jensensispermum* differs from any known Cycad in its complex chalaza, viz. the large thickened area connected at one end only with the hilum and penetrating deeply into the concavity of the endosperm. As already discussed such a structure is known to exist in Recent plants, for example in the Palmae but once again it is stressed that there is no intention of suggesting close relationship with Palms which differ in the form of the seed, absence of a large gibbous hilar scar, absence of a pulpy integument and of a comparable hilar cavity. It is suggested here that the Cycadean features may perhaps justify provisional reference to Cycadophyta pending further evidence. If this position can be entertained, the Utah seeds must belong to an entirely unknown family within that alliance.

It is possible to go one step further and to speculate whether *Jensensispermum*, with its complex chalaza unlike that of both Cycads and Gymnosperms, could be a primitive Angiosperm. But in the present state of our abysmal ignorance of what primitive Angiosperms were like, such speculation probably serves no useful purpose



FIGS. 26-28. *Jensensispermum redmondi* gen. et sp. n. Fig. 26. Seed looking onto chalazal region after abrasion of smooth layer so that the fibrous tissue diverging from hilar region, *h*, is exposed. *s*, sunk area to rear of endosperm exposed by shrinkage of chalazal region. *en*, dorsal rounded edge of endosperm seen from behind with fine fibres diverging radially from margin of chalaza. Figs. 27, 28. Detached endosperm, *en*, freed by abrasion and decay of the chalazal region, *ch*, of which slight traces only remain. *e*, embryo scar. Fig. 27. Almost true profile. Fig. 28. Tilted to show more of the outer surface of the endosperm.

although it seems right to draw attention to such a possibility. As Arnold (1959: 7) has said of ancient fossil angiosperms “the detached condition of the organs makes it impossible to bring together enough characters for the recognition of new families”, and again, “many angiosperm families have risen and disappeared during the known course of their history just as families have in other groups, but means of recognizing them have not been devised”. It seems advisable therefore at present to resist the temptation to build an ancestral castle upon such an insufficient foundation as the imperfect knowledge at present at our disposal. We can only hope that further discoveries will reveal missing characters of this plant which will demonstrate beyond doubt its true affinities.

The fossil is depicted with the micropyle directed downwards and the chalaza occupying the upper half of the seed. This is purely a conventional arrangement pending the discovery of a sporophyll or inflorescence with seeds in the position of growth. It is quite conceivable that the micropyle was upwardly directed with the chalaza occupying the lower half of the seed.

GYMNOSPERMAE

CONIFERALES

Family TAXODINEAE

Genus *SEQUOIA* Endlicher*Sequoia* sp.

(Pl. 8, figs. 75-79)

DESCRIPTION. The record of this genus is based on three cones which while affording evidence for generic determination are not sufficiently well preserved for specific diagnosis. All are ovoid with numerous spirally arranged peltate scales having lozenge-shaped escutcheons of which the breadth is greater than the height. The escutcheons meet edge to edge and appear to have been virtually closed when the cones were embedded. Towards the base and apex of the cones the scales diminish in size and owing to the poor preservation in these positions individual scales are there somewhat obscure. The best preserved specimen has a short stalk ; its length, including the stalk, being 23 mm. and its transverse diameters, 15 by 14 mm. Except where slight distortion has caused some confusion, the escutcheons in this specimen are clearly displayed, their maximum dimensions being 8 to 9 mm. broad and about 4.5 mm. high. Some appear to be shallow-convex superficially with an obscure transverse median ridge bearing an umbo ; others have a transverse median furrow (Pl. 8, figs. 75, 76). Traces of radial irregularities are preserved near the edges of the escutcheons indicating that the scale surfaces are reproduced in this specimen. About twenty scales can be counted on the better preserved side so that at least forty must have been borne on the entire cone.

The largest cone, about 30 mm. long, 22 by 17 mm. in maximum diameter, may have had as many as eighty scales some forty being visible on the better preserved side. Its escutcheons, 7 to 9 mm. broad, 3 to 4 mm. high at largest, are represented by light grey calcite clearly delimited by ridges of darker calcite along their margins (Pl. 8, fig. 77). Unfortunately, the surfaces representing the escutcheons show no structure or ornamentation in this specimen and appear to be purely mineral infillings of spaces formerly occupied by the distal ends of the scales. Nevertheless the specimen is of great value for it has been fractured rather irregularly not far below the middle and is about the only Utah plant yet seen which may give important information on an artificially fractured surface. The fracture must have passed in part (but only in part) along a natural plane of weakness caused by incipient separation between scales. Along this plane a thin film of calcium carbonate has infiltrated. Upon it the form and arrangement of the flattened seeds is obscurely reproduced in dark grey calcite (Pl. 8, fig. 78). This contrasts clearly with the whitish area between the seeds and the exterior of the cone representing scale surfaces. The seeds are radially arranged in relation to the cone axis, their outer ends being situated about half way between axis and external surface, their length somewhere about 4 mm. Their breadth, about 2.5 mm., when compared with that of the escutcheons suggests that at least two seeds were borne side by side on a scale but there may have been other seeds

obscured by a certain amount of overlap. The broad hilar end, by analogy with *Sequoia*, was directed towards the exterior of the cone. It may be indicated by a slight excavation on the two most distinct seeds. In one small patch near a seed margin there are impressions of rounded equiaxial pits, about 0.018 mm. in diameter comparable with the pits on seeds of living *Sequoia*. Hence there is reason to regard them as representing cells rather than crystalline structures. If so it is the only Utah plant yet seen which provides evidence of cell structure. The above interpretation is supported by the fact that the cells are much smaller than the inorganic crystalline structures which sometimes simulate cells in this material.

The third cone (V.51617) (Pl. 8, fig. 79) shows several clear escutcheons but many are obscure so that the scales cannot be counted even approximately as in the other two specimens. It is about 18 mm. long, 14 by 11 mm. broad, and is somewhat distorted obliquely.

REMARKS. The spirally arranged scales with lozenge-shaped escutcheons ornamented as described and the slender evidence as to the seeds all point to the genus *Sequoia*. *Metasequoia* and the Cupressineae are definitely excluded from relationship by the spiral arrangement of the scales in the fossil. Reference is made to the geological range of *Sequoia* on p. 141.

? Family TAXODINEAE

Genus *HILLISTROBUS* nov.

DIAGNOSIS. Small cones (?male) with spirally arranged imbricate scales narrowed at apex to form elongate tip, arising at right angles to cone axis, then bending upwards at a right angle at surface of cone. Bearing on their lower surface a number of rounded bodies (?anthers) sometimes exposed where abrasion has removed the overlapping tips of scales immediately below.

TYPE SPECIES. *Hillistrobus axelrodi* gen. et sp. n.

Hillistrobus axelrodi gen. et sp. n.

(Pls. 8, 9, figs. 80-87; Text-figs. 29-32)

DIAGNOSIS. That of the genus.

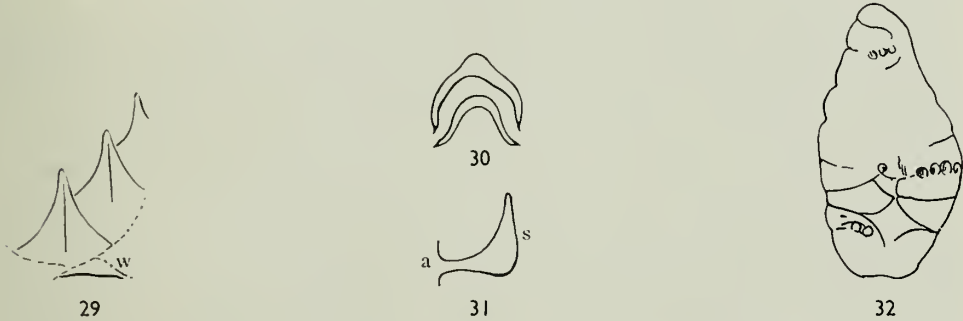
SYNTYPES. Brigham Young University, Utah, Nos. 40-42.

DESCRIPTION. *Cone*. Five small cones with uniform characters and one somewhat larger specimen (represented by the lower half only) may belong to a single species. There are also several cone fragments which are probably related. In addition a twig tip has leaves so similar in character to the lowest scales of some of the cones that it seems reasonably certain that the foliage belongs to the same plant rather than to *Sequoia* which it also somewhat resembles.

A complete ovoid cone, 12 mm. long, 7 by 8 mm. in transverse diameter is well preserved on one side (Pl. 8, fig. 80) but somewhat obscure on the other. Its thin scales are spirally arranged, overlapping with markedly acuminate tips having slightly

concave lateral margins. The extreme tips in this cone are usually broken, the scale margins are thin and delicate. They may appear irregularly and coarsely denticulate; the denticulations are probably not original but the result of a tendency of the edges to split. Each scale shows an obscure longitudinal median rib and finer longitudinal striations. At least twenty scales can be counted on the well preserved side suggesting that the complete cone must have borne about forty to fifty.

A second cone (Pl. 8, fig. 81) has similar characters but owing to crushing the scales stand out less sharply. Both surfaces of this specimen show traces of small ovoid or globular bodies, about 0.75 mm. in diameter, projecting between some of the scales. It is not clear in this specimen whether they have a structural significance or are due



FIGS. 29-32. *Hillistrobus axelrodi* gen. et sp. n. Fig. 29. Diagram to show parts of cone scales exposed at surface of cone with acuminate tips, slightly concave margins and slight median longitudinal angles. Dotted lines indicate where overlapping scales below are broken. *w*, worn stump of a cone-scale which has lost its elongate tip by abrasion. Fig. 30. Diagram based on part of a transversely fractured cone where thickness and overlap of scales are partly shown in section. Fig. 31. Diagram to show how, seen in longitudinal section, the scale arises at right angles to axis, *a*, at centre of cone; then takes a sharp right angled bend upward at surface of cone, *s*. At the upward bend there is a thickening to close gap between it and scales below. Fig. 32. Rough diagrammatic sketch based on specimen 47 to show rounded bodies (? anthers) fringing worn edges of some scales.

to some peculiarity of preservation. The number of scales cannot be counted. Length of cone, 17 mm.; diameter, 11.5 by 9.5 mm.

A third cone is the lower two-thirds (approximately) of a more elongate specimen. It shows clearly the attenuated form of the scales and some of the scale tips are perfect (Pl. 8, fig. 85). The basal scales are small and the two lowest may possibly be foliage leaves. They are opposite and seem to link this species with the foliage mentioned above. Above this pair of (?) leaves the scales are spirally arranged as in other specimens. The cone is fractured transversely above but unfortunately the section shows no structure. Length of cone as preserved, 14 mm.; diameter, 9 mm. The appearance of this specimen and the absence of any clear footstalk suggest that the cone was not sharply delimited from the foliage but gradually merged into it.

The cone depicted in Pl. 8, figs. 82, 83 although the upper half only of a small ovoid specimen displays very clearly the spirally arranged scales with well preserved

complete tips. The scales become very small at the apex of the cone. One surface has suffered much abrasion which has removed the thin pointed tips leaving only the worn rounded stumps of the thick middle part of the scales. On the worn surface one or two subglobular bodies are again seen between the scales and on the transversely fractured surface which forms the base of the specimen they are also present but their arrangement is obscure. The fractured surface indicates that the scales arise at right angles to the cone axis and only at the circumference of the cone do they bend upwards at a right angle to form the overlapping subtriangular pointed scale tips described (Text-fig. 31). The lower edge of the scales at the circumference appears to be slightly thickened so as to meet in close contact the surface of scales immediately below. Maximum length represented, 10 mm.; diameter, 9 mm.

A fifth cone (46) is a mere fragment. The apex and half the surface have gone and the base is slightly incomplete. Unfortunately the oblique-longitudinal section shows no structure. There is one pointed scale with tip preserved, and another much worn and therefore rounded. The obscure rounded bodies are seen on the worn surface and may be exposed by abrasion of scales which overlay them. Length of fragment, 14 mm.; breadth, 9 mm.; thickness from exterior to sectioned surface, 5.5 mm.

Another cone (44) is very obscure and is obviously the lower half of a larger one about 15 mm. in diameter. 11 mm. of the cone length are preserved. Unlike all other specimens there is a short footstalk but the details of scales are obscure at the surface which is much corroded. The basal scales correspond in character with those of specimen (41). Irregular rounded projections here appear to have no significance structurally. The transverse fracture does nevertheless show, in places, the thin scales, in section, overlapping others with concave upper and angled lower surface and attenuated margins (Pl. 9, fig. 87; Text-fig. 30).

The cone (47) is much distorted, abraded and imperfect but it shows definite rounded bodies fringing the worn edges of some of the scales (Text-fig. 32). Other specimens are too broken to merit individual description and make no special contribution to the elucidation of this species.

Foliage. (Pl. 8, fig. 86). A small twig tip, 13 mm. long, incomplete at the extreme apex which may have borne either a cone or a foliage bud. It is 6.5 by 5 mm. in maximum diameter, differences of breadth which may be due to a slightly bifacial form. The small spirally arranged leaves are imbricate, scale-like, closely investing the stem, angled medianly on the lower side especially at the sides of the twig in the broader plane. There is no evidence of cell structure. All or part of twelve or thirteen leaves can be counted on the broader surface. The longest marginal leaf is about 6.5 mm., its breadth from margin to midrib about 2.5 mm. The longest leaf seen on the broader surface is about 6 mm. and its total breadth from margin to margin, 3.25 mm.

A larger twig fragment, 26 mm. long, 8 by 10 mm. broad shows lozenge-shaped leaf scars but is in poor condition. The scars and outer tissues of the twig are worn away at one end exposing a woody axis with no structure preserved. This fragment may belong either here or with *Sequoia*.

REMARKS. Once again the interpretation of this species is difficult because of the crystalline character of the casts by which it is represented. Specimens were shown to Prof. T. M. Harris but were unknown to him. He drew attention to their superficial resemblance to *Sphenolepis* Schenk from the Wealden of Belgium (Harris 1953 : 5) represented by foliage and female cones but the specific limits of *Sphenolepis Kurriana* (Dunker) are, he pointed out, ill-defined. The scales of the Utah cones are certainly more markedly attenuated. Nor is the resemblance to the Wealden genus *Elatides* Heer (see Harris 1953 : 21) any closer. Whether a ligule is present or not on the upper surface of the scales cannot be ascertained. If these cones are female structures they certainly differ markedly in their thin overlapping scales with long narrow tips and lack of any definite ornamental escutcheon (Text-fig. 29) from *Sequoia* (p. 157). The presence of the small ovoid or rounded bodies described above, especially when these appear to project from the lower side of the scale, raises the question whether the cones could be male organs and the rounded bodies anthers. There is nothing in the form of cone or scale to preclude this possibility. Whereas many coniferous male cones are very small, some, those of *Araucaria* for instance, may be larger than the fossil cones. Traces of the "anthers" are visible both in specimens with abraded rounded scales and in those which still carry the unworn attenuated tips. They may however be a result of partial decay and abrasion and not definite organs. In spite of the many gaps in our knowledge of this species it seems to have readily recognizable characters. In order, therefore, that it may be kept in mind in future investigations, it has been called *Hillistrobus axelrodi*. The reason for this name is explained on p. 141.

A number of syntypes have been selected so as to demonstrate as far as possible the characters of scales and cones.

Genera ?

(Pl. 9, figs. 88, 89)

A cone 19 mm. long, 15 mm. in transverse diameter, without foot-stalk, having spirally arranged scales (Pl. 9, fig. 88). Three small scales at the extreme base are thin especially at the margins and narrowed to a point at their distal extremities. Scales over the main body of the cone appear to have suffered much abrasion which has removed their thin imbricate distal ends (if they ever existed) leaving the thickened rounded, smooth middle part of the scale projecting (cf. the abraded side of *Hillistrobus* cone Pl. 9, fig. 83 which they resemble but on a larger scale). These worn scales, almost as broad as the cone itself and about 4 mm. high, are difficult to count. About fifteen are visible on one surface suggesting at least thirty on the whole cone, a smaller number than that on the male(?) cones of *Hillistrobus*. Above the scales in some instances is a low triangular flattened area, possibly the part impression of the former distal prolongation of a subjacent scale on a film of calcite between it and the scales above. The form of the triangle suggests that the prolongation, if it existed, must have been shorter than in *Hillistrobus*. It is permissible to speculate whether this larger cone could be a female example of that genus in a somewhat

abraded condition, but there is no evidence to confirm or refute this suggestion. It can be stated confidently that the *Sequoia* cones described on p. 157, even abraded, would be unlikely to produce the appearance here shown. In fact there are no grounds for regarding this cone as ever having had scales with escutcheons meeting edge to edge as in *Sequoia*.

A red siliceous cast (Pl. 9, fig. 89) 22 mm. long as preserved (imperfect at the tip), 15 mm. in transverse diameter is too ill-preserved for speculation as to its relationships. The scales are small, spirally arranged, overlapping, sharply pointed above, with very slightly concave margins flanking the point and a slightly convex outline below the broadest part exposed at the surface. Maximum length of scale exposed, 3 mm.; maximum breadth, 4 mm.

INCERTAE SEDIS

Genus *CARPOLITHUS* Linnaeus

Carpolithus provoensis sp.n.

(Pl. 9, figs. 90-92; Text-figs. 33-36)

DIAGNOSIS. Integument or cupule rounded-obconical elongate, lobes free only at flattened apex where there are five ? pointed unequal segments. Base with two short unequal facets inclined at an angle of 90° and, on opposite side, a short deep cleft. Surface irregularly longitudinally furrowed, many furrows short and discontinuous.



33



34



35



36

FIGS. 33-36. *Carpolithus provoensis* sp. n. Fig. 33. Apex with appearance of sepals, four of which are clearly seen and a fifth, partly visible is indicated also by the spacing. Fig. 34. Side, showing deep basal cleft or furrow and flattened apex. Fig. 35. Opposite side, showing two unequal basal facets. Fig. 36. Side at right angles to fig. 35. One facet here appearing as a basal excavation, the other facing the observer.

Transverse nervules divide surface into rectangular areas. Length, 26 mm.; apical diameter, 11 by 9 mm.

HOLOTYPE. Brigham Young University, Utah. No. 50.

DESCRIPTION. Seed enclosed in an integument or cupule which is rounded-obconical and elongate, its lobes united except at the flattened apex. Base more or less pointed with a short deep cleft or furrow (about 4 mm. long) on one side (Pl. 9, fig. 91; Text-fig. 34) and two unequal facets, inclined to one another at an angle of about 90° on the opposite side (Pl. 9, fig. 90; Text-fig. 35). One facet is 10 mm. long with maximum breadth of 4 mm.; the other is 7 mm. long with maximum breadth about 3 mm. The furrow and facets could be caused by pressure from a stem and adjacent seeds. The whole surface is irregularly longitudinally furrowed, many of the furrows being short and discontinuous, others longer, none extending throughout the length. Remains of transverse nerves are also seen which appear to divide the surface into small rectangular areas. There may be slight indications of branching and anastomosing of nerves. In places the surface appears finely longitudinally striate and perhaps formed of small equiaxial rounded cells about 0.038 mm. in diameter, but these are obscure. Cell structure and furrows are continued onto the facets suggesting these are due to secondary pressure. Apex partially hidden by five? sepal-like pointed segments of the integument which bend over it crossing the apical margin at a sharp angle. Segments not all equal in size, extending almost to the centre of the apex, partially obscured by adherent matrix (Text-fig. 33). Length of integument, 26 mm. Diameter at apex, 11 by 9 mm.

DISCUSSION. Nothing is known of the interior of this specimen but it may be supposed to enclose a seed. Relationship to Pteridospermae is not excluded by the superficial features which are the sole available evidence. Andrews (1963, text-figs. 4-9) illustrates a number of Pteridosperm seeds covered by integuments showing considerable variation in the degree of fusion of the lobes. In his text-fig. 18 Andrews illustrates a *Lyginopteris* seed with apex having the same form as the fossil but otherwise unlike it. Since this one much younger specimen only yields such limited information nothing definite can be said as to affinities. The specimen is referred to the form-genus *Carpolithus* as *C. provoensis* sp. n.

Carpolithus radiatus sp. n.

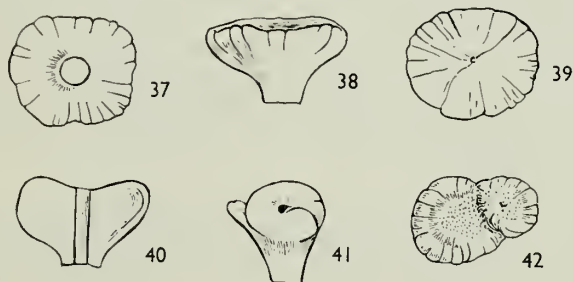
(Pls. 9, 10, figs. 93-130; Text-figs. 37-42)

DIAGNOSIS. Stalked circular peltate seeds about 8 to 15 mm. in diameter with thick integuments enclosing in some cases cast of seed cavity of albuminous seed. Seed casts compressed at right angles to axis sometimes having a central depression connected with the margin on one side by a radial channel. Micropyle central? Chalaza on lower surface contiguous with stalk. Hilar scar marginal indicated by truncation on cast. Few specimens showing narrow radial cavities instead of seed-casts (? anthers). Some of these have a stout central canal with fibre strands extending throughout their length.

SYNTYPES. Brigham Young University, Utah, Nos. 51, 53, 58-60.

DESCRIPTION. A plant, represented by over thirty specimens, difficult to describe because not fully understood. This is partly due to the great limitations of this type of preservation, partly to the incomplete, fragmentary character of the material, and partly to the fact that nothing comparable, either living or fossil is known. The specimens show variations of form within certain limits and differing degrees of abrasion. From a few which display something of the internal structure two distinct organs are probably represented but from the external characters alone it is not always easy to discriminate infallibly between them. In general all are peltate with thick central stalk, broken off shortly, which widens upwards at first gradually, then suddenly to produce a subcircular apical disc of varying thickness (Pl. 9, figs. 93-100; Text-figs. 37-39). The lower surface of the disc is obconical or convex (51, V.51619; Pl. 9, figs. 94, 95, 100, 101; Text-figs. 38, 41), the upper surface may be shallow obconical or concave (51, 55), flat (52) or slightly convex (58; Pls. 9, 10, figs. 93, 96, 117, 119). The lateral margin of the disc may be sharp (? if worn) but is more often rounded and inflated in varying degree (52, 54, V.51621, V.51622; Pls. 9, 10, figs. 97, 109). A few specimens exhibit marked dorsiventral inflation (54, V.51622; Pl. 10, figs. 113, 115). In almost all cases both surfaces show radial furrows occupied by fibres traceable either for short, variable distances or from the margin to the centre. In general these fibres diverge from the stalk below (or from its direction) and converge towards the centre of the disc above so producing an irregularly fluted margin. One specimen (58) is partly covered by an outer (?) epidermal, layer preserved only on the upper surface. It is rugose and has a central mucro (Pl. 10, fig. 119), a somewhat similar mucro is seen in (60) (Pl. 10, fig. 127). This latter had been fractured in a median longitudinal plane before fossilization and shows a central fibrous axis terminating above in the mucro (Pl. 10, fig. 128). Two other longitudinally fractured specimens (57, V.51623; Pl. 10, figs. 124, 126) show the central axis as a hollow canal. V. 51623 and 60 appear to have narrow radial cavities flanking the axis (Text-fig. 40) while in (57) there may be an obscure cast of such a cavity. One specimen (62) has superficial rugosities corresponding in direction to the furrows and alternating ridges described above. These could indicate a pulpy layer now dried and partly shredded, commonly wholly abraded. The stalk of this specimen, also of (56), displays in cross section a central cavity and coarse radial structure emphasized by a tendency to crack (Pl. 10, fig. 118). One club-shaped specimen (61) with ellipsoid head instead of a dorsiventrally compressed disc has similar fibres converging to the apex (Pl. 10, figs. 129, 130). In spite of its different shape it is so closely comparable with the others in its surface that it is regarded provisionally as belonging to the same species. It may represent an immature seed or a barren shoot tip. The other differences alluded to whether in degree of inflation or in form would all probably have been attributed to different stages of development but for the few imperfect or abraded specimens which indicate that true internal structural differences exist. A few of the more inflated examples show the internal cast of an albuminous seed, the seed having been exposed before fossilization by decay or abrasion of its integuments which form the disc. Such

casts which are only slightly dorsiventrally compressed have an inflated rounded margin (53, V.51620, V.51622). All show a marked central depression which may be continued to the margin along one radius as a channel. Thereby the effect of a curved seed cavity is produced (Pls. 9, 10, figs. 102, 105). A small twig embedded in the endosperm of (54) suggests that this tissue in life was fairly soft. Clearly such well filled seed-bearing specimens are of different structure and significance from those referred to above with flattened radial cavities. The true nature of the latter cannot be established on the evidence of available material but they could be male organs or barren shoots with internal floats. The former seems to be the more probable hypothesis. Unisexual organs are common in Mesozoic vegetation. A few of the inflated specimens (especially 58 but the evidence is also seen in 63, V.51622, V.51625)



FIGS. 37-42. *Carpolithus radiatus* sp. n. Fig. 37. Base of a seed showing central stalk and radial marginal furrows. Fig. 38. Side, showing slight concavity of apex, sometimes present, and rounded margin. Fig. 39. Apex, radial furrows again shown diverging from central micropyle (?). Fig. 40. Median longitudinally sectioned specimen with central longitudinal canal and fibres and shallow radial cavity on right. Fig. 41. Apicolateral view of seed with internal cast (= endosperm) exposed by abrasion of integument. Central depression and embryo scar and channel between the latter and the margin are seen. On left is a second young seed (or ? shoot in early stages). Fig. 42. Apex of two contiguous seeds growing, almost fused, on the same stalk. Stippling indicates adherent matrix on their surfaces.

have lost the stalk and lower part of the integument, presumably destroyed before fossilization. In such instances a transversely rugose lower surface of the seed cast is exposed (Pl. 10, fig. 120). It recalls the tissues of the chalazal region in *Jensensispermum* (p. 156) but in the present instance the region is situated on the lower surface of the seed above the erect stalk (raising the question whether the chalaza in *Jensensispermum* should be placed below rather than above). The rugosities tend to diverge from a point near the circumference. In 63, V.51625 there is a marginal truncation at this point, emphasized by a raised rim. In 58 scar and rim are not clearly defined but the rugosities with marginal divergence are particularly clear (Pl. 10, fig. 120) as is the radial arrangement of the upper surface (Pl. 10, fig. 119). It seems probable that the point of divergence and truncation indicate the hilar scar at one side of the chalazal region as in *Jensensispermum*. The specimen which best shows the curved appearance and apical depression of the endosperm (53) also dis-

plays a small bud-like projection arising on the stalk at the opposite end of the diameter through the radial channel in the endosperm (Pl. 10, figs. 105, 106; Text-fig. 41). This may indicate the beginnings of a second seed or shoot (cf. also V.51626). That duplication of organs does occur is clearly visible in 59 (Pl. 10, figs. 121, 122) where two contiguous seeds on the same fused stalk are so closely addressed as to cause deformation of the larger one (Text-fig. 42). Except when seed casts or radial cavities are well developed or exposed by abrasion or fracture it is not always possible to be sure whether a given entity is (?) male or female (i.e. assuming that the specimens with radial hollows are, in fact, correctly interpreted as male organs).

The diameter across the apical disc varies from about 8 by 8 mm. to 15 by 11 mm. Frequently there is a maximum diameter while that at right angles to it is shorter. The diameter across seed-casts seen is 8 by 8 mm. to 11 by 12 mm. and 13 by 10 mm., and the dorsiventral thickness, 8 to 10 mm. The maximum length seen from the top of the apical disc to the lower end of the broken stalk is 10, 9 and 12 mm. The mode of growth of this plant is unknown and it is impossible on the present limited evidence to make any suggestion as to its systematic position. It may well represent an extinct phylum. While awaiting better information the species is described and figured as *Carpolithus radiatus*.

The temptation to regard it as a pedunculate fruit enclosing a seed has been resisted on account of the features which these seeds have in common with *Jensensispermum redmondi*: viz. the albuminous character and the relative positions of chalaza, hilum and micropyle in relation to the endosperm. Indeed the seed cast resembles a rather compressed seed of *Jensensispermum*. The similarity suggests kinship between the two but consistent compression and the radially ornamented and expanded integument around the flattened seed indicates that they must be distinct genera even if related.

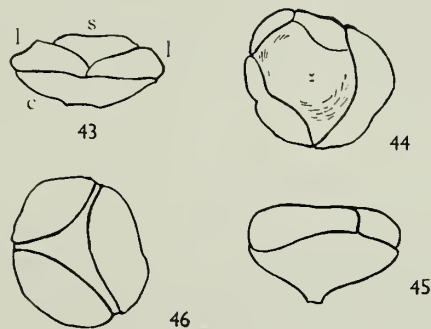
Carpolithus sp.

(Pl. 11, figs. 131-134; Text-figs. 43-46)

The appearance of two subglobular but somewhat crushed specimens is that of a "berry" partially enclosed in a cupule which is lobed above. The first (Pl. 11, figs. 131, 132; Text-figs. 43, 44) has been much compressed dorsiventrally so that it is now only about 9 mm. long but 26 mm. in transverse diameter. Its surface is abraded and rugose. No cell structure or tissues of any kind can be detected. The entity enclosed which could well be a seed is exposed naturally at the apex of the gaping cupule and, by abrasion, at the base also where cupule and attachment have been worn away (Pl. 11, fig. 132). At the equator a horizontal furrow may have structural significance but it may perhaps have been deepened as a consequence of crushing. Below the furrow the cupule is fused (Text-fig. 43). Above it is divided into four distinct low rounded lobes which extend up the sides for perhaps two-thirds of its original length. The lobes are unequal (Text-fig. 44). Two adjacent larger lobes occupy about two-thirds of the circumference while two smaller ones

together occupy the remaining third (Pl. II, fig. 131). One of the smaller lobes appears to overlap the smaller and larger lobes adjoining it. The second smaller lobe is overlapped by the second larger lobe. The two large lobes are barely contiguous at their junction.

The second specimen, although also much abraded is relatively unworn and uncrushed below but flattened and compressed above. It shows remains of a prominent pointed attachment situated medianly on its broadly obconical lower surface (Pl. II, fig. 134; Text-fig. 45). The demarcation between the fused lower and lobed upper parts of the cupule is made more obvious by a difference in the colour of the cast. The lower part is of grey calcite and the upper of red. There are only three lobes, approximately equal in breadth, without evidence of mutual overlap.



FIGS. 43-46. *Carpolithus* sp. Fig. 43. Side view of dorsiventrally compressed seed, *s*, in cupule, *c*, with separate lobes, *l*, above the equator. Fig. 44. Same, apex, showing four unequal lobes surrounding and partially concealing the seed. Fig. 45. Another specimen, side, with entire cupule on lower part, lobed segments above. Fig. 46. Same, apex, showing the three lobes largely overlapping and obscuring the much flattened seed.

The upper limits of one lobe are a little obscure (Pl. II, fig. 133; Text-fig. 46). Diameter of this specimen, 27 by 21 mm. Length including attachment, 25 mm.

The true nature of the object within the cupule can only be guessed in the absence of evidence as to its structure or integuments but it could be a seed of Pteridospermous type. In the circumstances it is impossible to do more than describe the two specimens as *Carpolithus* sp.

A number of isolated, irregular, featureless, subglobular bodies also occur in the deposit. While they have the appearance of tubers, they could equally well be ill preserved seeds, like those in the cupules described above or fungi or algae. They are of comparable size but appear to lack any distinctive features apart from several obscure circular depressions filled with matrix which may or may not be of any significance. One or two of these organs are shown in Pl. 12, figs. 148, 149 (cf. also V.51813-14).

Carpolithus sp.

(Pl. II, figs. 135-145)

About a dozen specimens, almost all of which are considerably broken, show certain features in common. They are more or less fusiform and longitudinally striate. Some of the striae are deep and well marked and may extend throughout the length preserved. Others are shallower and impermanent. One (Pl. II, figs. 135, 136), pointed at one end, truncate through a break at the other, shows close-set finer sinuous furrows and ridges between the deeper conspicuous ones. There seems to be a tendency for these objects to split longitudinally along the more conspicuous and persistent grooves, but there is no evidence of splitting into a definite number of segments. A possible alternative interpretation is that these bodies are formed by the partial fusion of separate segments. One (Pl. II, fig. 145) is pointed at both ends. Another (Pl. II, figs. 143, 144) is pointed at the perfect end but broken at the other. While (V.51628; Pl. II, figs. 137, 138) appears to have been pointed at both ends although both are very slightly imperfect. Two specimens are peculiar in having at one extremity an expanded disc-like region (Pl. II, figs. 139-142) separated by a narrow neck from the main area. This could be a crushed cupule but has the appearance of a sucker-like attachment. The preservation is too obscure for its true nature to be ascertained. In both the disc is bent, possibly secondarily but prior to fossilization, almost into the plane of the major part described above. Some at least of the furrows extend onto the disc. A smaller object, (74) embedded in matrix (only about 13 mm. by 7 mm., slightly imperfect at one end) shows as an impression in the matrix what may be also the impression of a small cupule. It is not clear whether this should be grouped with the above.

Unfortunately none of these specimens, even when broken and imperfect shows any shred of evidence as to structure or organs within. There are therefore no grounds for suggesting that a seed is enclosed by a ridged and furrowed integument. It is impossible, in the circumstances, to form any opinion as to their nature, but their relationship may at some future time be determined if better preserved material showing these characteristics is found. Consequently, it seems worthwhile to illustrate them and to publish this brief account.

(Pl. II, figs. 141, 142)

Dimensions of specimens: (70) Length, including disc, 38 mm. Breadth (as crushed), 23 by 10 mm. Breadth across constriction which delimits disc, 18 mm. Length of body above disc, 29 and 25 mm. respectively on opposite sides.

(Pl. II, figs. 143, 144)

(71) Organ with no disc preserved. Length, 40 mm. Breadth (as flattened), 21 by 10 mm. The "segments" in this specimen appear to be somewhat obscured by matrix which may, or may not, represent an outer layer of integument.

(Pl. II, figs. 135, 136)

(68) Length broken at one end (no disc) about 23 mm. Breadth, 15 by 6 mm.

(Pl. II, figs. 137, 138)

(V.51628) More slender, perhaps immature, slightly imperfect at both ends. Length, 26 mm. Breadth, 12 by 5 mm.

(Pl. II, fig. 145)

(72) One side much obscured by adherent matrix the other partly obscured. Both ends more or less complete but no "disc" preserved. This fact suggests that the "disc" is a cupule if the specimen is really related to the others. Length, 30 mm. Breadth, 18 by 12 mm.

(Pl. II, figs. 139, 140)

(69) Smaller with well marked "disc" and almost perfect apex. Length, 25 mm. Breadth, 11 by 9 mm. Breadth of neck, 10 mm Breadth of disc, 14 mm.

In addition some broken or imperfect specimens not figured and two (V.51629) in the British Museum (Natural History). All others Brigham Young University, Utah.

UNKNOWN ORGANISMS

(Pl. II, fig. 146 ; Pl. 12, figs. 147, 150-154, 156, 158)

A large subcircular body, now much flattened apparently dorsiventrally. An irregular pitted central prominence on one side (Pl. 12, fig. 150) suggests an attachment. Beyond this central region fine concentric striations or wrinkles are visible. On the opposite broad surface similar features are seen (Pl. 12, fig. 151, cf. also V.51807-08, V.51811-12). The nature of these bodies is obscure. Diameter of figured specimen 40 by 36 mm.; height, 16 mm. A second imperfect specimen, broken so as to display a longitudinal section shows a central cavity now wholly occupied by quartz crystals (Pl. 12, fig. 152). The significance of the superficial concentric structure is not clear. It suggests a mode of growth emphasized and made conspicuous by contraction on drying.

Numerous similar cake-like organisms show in varying degree a tendency to disintegrate radially and/or concentrically. Some are larger, others smaller than the specimens described above. While they bear a superficial resemblance to some fungal fruiting bodies they show no clearly defined diagnostic character on which a satisfactory determination can be based (see p. 143).

In some cases these bodies are twinned (Pl. 12, fig. 147) two growing in close contiguity causing mutual flattening along the contiguous surfaces. The figured specimen is 30 by 25 mm. in diameter, the individuals of the pair being about 17 and 12 mm. in maximum diameter respectively. Some apertures on the surface could be due to crystalline inorganic structures. There is no definite evidence for interpreting them as perithecia.

Pl. 12, fig. 156 is a distorted subglobular body, 18 by 16 mm. in diameter, which has started to split into petal-like segments. It has a peculiar irregularly cracked and

fissured surface. The superficial appearance suggests fungus but satisfactory evidence of its nature is again lacking.

The object in Pl. 12, figs. 153, 154 has a curved obconical form with shallow convex upper surface. Only half of the original appears to have been preserved it having split longitudinally through the curved pointed end and along the broadest diameter of the convex surface prior to fossilization. It has a fibrous appearance, the "fibres" diverging from the pointed end and branching repeatedly. Where they impinge on the convex surface they produce a radial structure. Whether they are true fibres or of chemical origin seems doubtful. There seems to be a tendency to shred and weather along the lines they produce. One margin of the fragment from the point to the edge of the convex surface is 30 mm. long, the other 20 mm. The thickness from the margin of the rounded outer surface to the plane of fracture is 15 mm. The maximum diameter of the convex surface is 39 mm. There is no evidence of an outer integument but the roughness of the surface preserved suggests that if the body is of organic origin such an integument would formerly have covered it. No suggestion as to the nature of this specimen can be made. The fact that it might show the internal structure of bodies like that in Pl. 12, figs. 150, 151, pure moulds of hollow casts of former entities, should be remembered (cf. V.51804, V.51815).

It is quite impossible either to describe or figure the innumerable tuber, alga, or fungus-like bodies which occur in this deposit. They show great variety of form and size. Two final examples have been selected for illustration because they bear a purely superficial and misleading resemblance to pods of higher plants. One is elongate with a narrow rim, and is incomplete at each end. It is 35 mm. long, 14 mm. broad, 4 mm. thick (Pl. 11, fig. 146). The other is flattened and subcircular, 21 by 23 mm. in diameter, also with an obscure rim (Pl. 12, fig. 157). In both the surface is irregularly pitted and around the edge cracked and fissured. No explanation of these curious bodies can be offered.

Thorn

(Pl. 12, fig. 155)

A large detached thorn, down curved as seen in lateral profile so that its outline above is slightly convex and below slightly concave. The base is broad, subelliptical, with a somewhat convex surface which lies oblique to the thorn itself which is therefore asymmetric on the two sides. The more convex side carries a median rounded angle throughout its length. The base measures 28 mm. longitudinally by 18 mm. transversely. A straight line drawn from the upper edge of the base to the tip of the thorn measures 28 mm. and from the lower edge to the tip only 21 mm. A smooth surface is preserved all over the longer more convex side but only at the proximal end of the shorter side. Here it is abraded towards the tip exposing a coarsely fibrous structure. As there is nothing to connect the specimen with any other plant remains its systematic position cannot be determined and no name can be given.

POSTSCRIPT

After this MS. was completed a periodical reached the British Museum (Natural History) in December 1964 which included a brief note on some similar fruiting organs and one or two additional ones from the northern Henry Mountains (flanks of Mt. Ellen) in south-eastern Utah. They were apparently derived from the Morrison bedrock at the collecting site. The author of the note, Charles Bass (1964: 94, 95; two half-tone figures in text each showing a number of the specimens) states that they are suggestive of both angiosperm and gymnosperm fructifications although no formal identifications had been made. His MS., accepted on 25th April, 1964, was published in July 1964. Among specimens figured are *Behuninia*, *Jensensispermum* and *Carpolithus radiatus* all described in the foregoing pages in which the present writer's views on the affinity of these forms is clearly stated.

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EXPLANATION OF PLATES

Transverse striations in the plates are due to faulty technique in collotyping and are not structures present in the fossils or faults in the original photographs.

All specimens are from the Morrison Formation, Utah. See p. 139.

PLATE I

Behuninia joannei gen. et sp. n.

FIG. 1. Syntype. Detached distal end of a sporophyll, upper side, incurved over two young seeds. Left side incomplete as indicated by broken line. Cut lower end of fragment at *s*. Dissected free ends at *t*. $\times 6$. (1.)

FIG. 2. Same, lower side. Axis, *a*, between young seeds shows longitudinal nerves connected by slender transverse branches. $\times 6$.

FIG. 3. Syntype. A young terminal seed, lower side, attached to rachis, *r*. Attachment facet in lower half of figure. $\times 6$. (2.)

FIGS. 4, 5. Syntype. Two opposite obovoid seeds still attached to rachis, *r*. Longitudinal nerves are seen on the rachis and converging to the apices of the seeds. Fig. 4, upper side; fig. 5, lower side. $\times 3$. (4.)

FIG. 6. Seed in fig. 3, upper surface. $\times 3$.

FIG. 7. A young seed near distal end of sporophyll still attached to rachis. A second sub-opposite seed, borne at *s2*, is not preserved. $\times 3$. (3.)

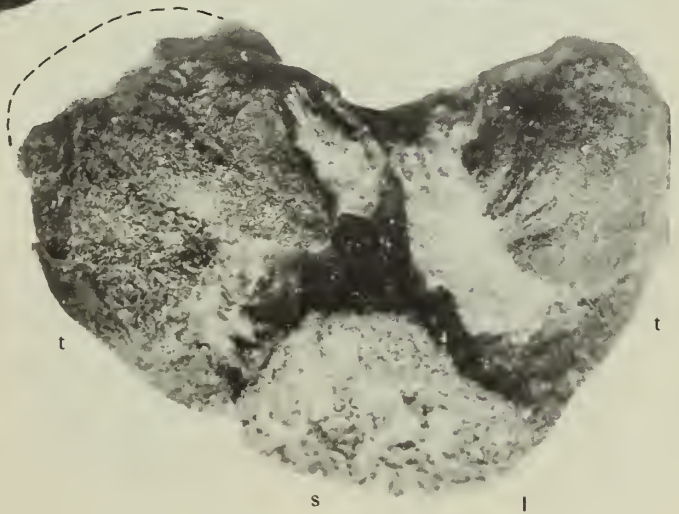
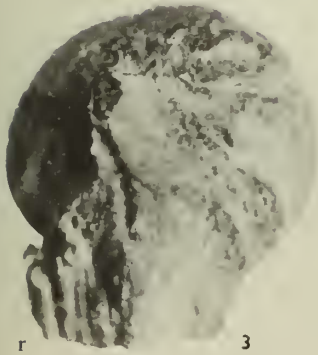
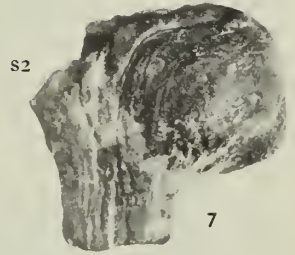
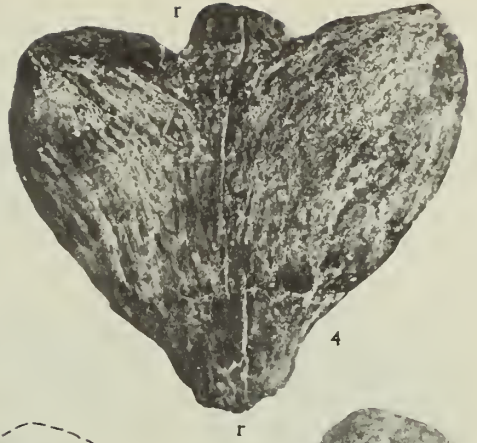


PLATE 2

Behuninia joannei gen. et sp. n.

FIG. 8. Pair of small subglobular distal seeds still attached. $\times 3$. (V.51588.)

FIG. 9. Pair of rounded seeds, *s*, attached to rachis, *r*, lower side. Endosperm of seeds exposed. $\times 2$. (V.51589.)

FIG. 10. Same, upper side, showing closer approximation of seeds. Lettering as in fig. 9. $\times 2$.

FIG. 11. Syntype. Pair of seeds, *s*, attached to broad rachis, *r*, lower side. Embryo vesicle at *v*. $\times 3$. (8.)

FIG. 12. Same, viewed from distal end. Embryo vesicle, *v*, preserved in grey matrix shows clearly in actual specimen, against pink endosperm. $\times 3$.

FIG. 13. Pair of abraded seeds still attached. Terminal embryo vesicle depression at *v*, rachis. *vl*, ?lateral embryo vesicle. $\times 2$ approx. (V.51594.)

FIGS. 14, 15. Syntype. Pair of larger ovoid seeds (one imperfect) attached to rachis, *r*. Terminal embryo vesicle at *v*. Fig. 14, lower surface, fig. 15, upper surface. In fig. 15 worn remains of longitudinal fibres are seen on left seed converging towards the terminal embryo vesicle. $\times 2$. (5.)

FIG. 16. Two unequally developed attached seeds, lower surface, showing discontinuous branched nervation. $\times 3.3$. (V.51590.)

FIGS. 17-19. Syntype. Somewhat abraded seed with dried pulp exposed forming irregular ridges which converge to the apical embryo vesicle. Lateral vesicle (?abortive) seen as circular scar from which furrow, *f*, runs to base separating a snout-like region, *sn*, from the rest of the seed, Basal area smooth because still retaining outer layers elsewhere abraded. (9.) Fig. 17, side $\times 2.5$. Fig. 18, side $\times 6.5$. Fig. 19, apex showing converging rugosities of dried pulp $\times 2.5$.

FIG. 20. Syntype. Rounded well-developed seed broken from axis. Apical embryo vesicle at *v*. Remains of striate fibrous integument or bract below with broken edge at *b*. $\times 2.2$. (7.)

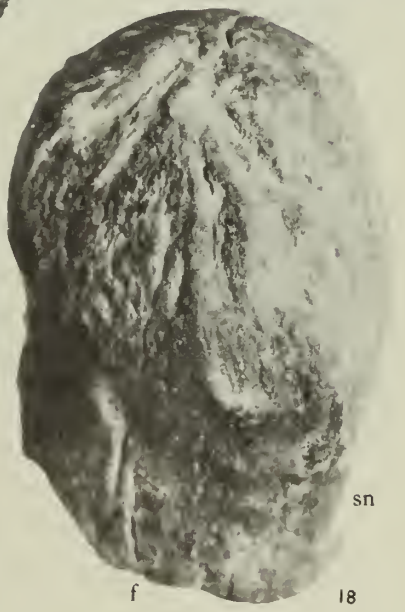
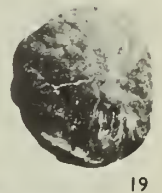
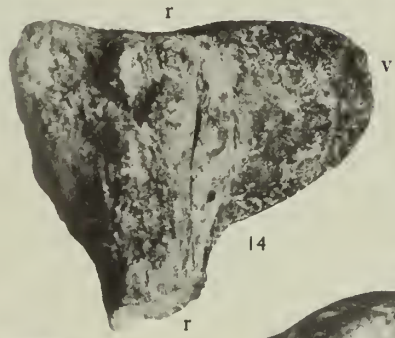
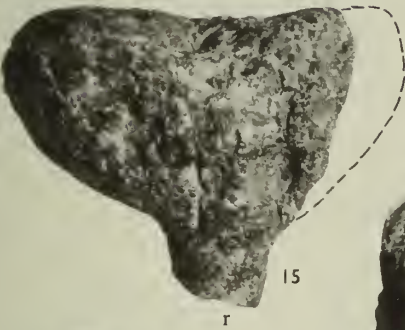
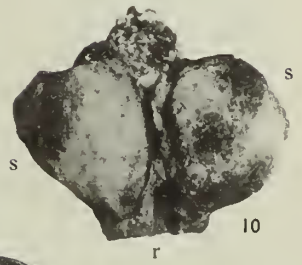
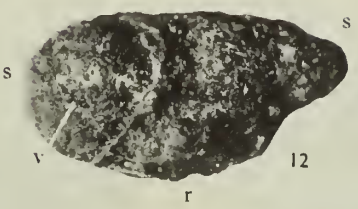
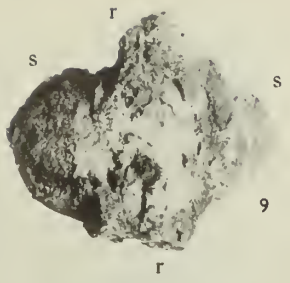
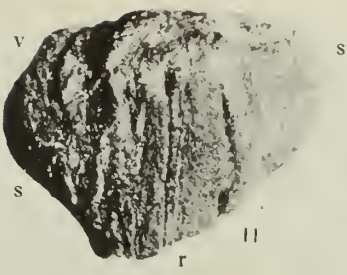
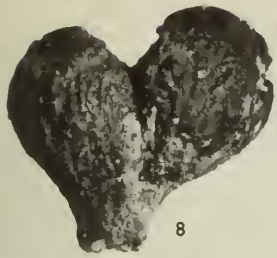


PLATE 3

Behuninia joannei gen. et sp. n.

FIG. 21. Syntype. Seed, apex, with hard integument exposed by abrasion showing apical vesicle (white circular scar) and simple longitudinal fibres diverging from it. $\times 2.5$. (10.)

FIG. 22. Same, attachment side showing facet, *f*, below, and longitudinal fibres diverging from apical vesicle to margin of facet. $\times 2.5$.

FIG. 23. Seed cast representing endosperm; terminal embryo vesicle at *a*. Lateral vesicle light coloured depression. Longitudinal furrow from the latter separates snout, *sn*, from rest of seed. Base broken. $\times 2.2$. (V.51593.)

FIG. 24. Same, apex. Terminal vesicle seen as light coloured patch and attachment facet, *f*, forms a low projection in profile. $\times 2.2$.

FIG. 25. Detached seed. Attachment side; *f*, attachment facet. Branching fibres of surface well preserved. *sn*, snout. $\times 3$ approx. (20.)

FIG. 26. Same, opposite side with well preserved rugose external surface. Snout-like region on right. $\times 3$ approx.

FIG. 27. Much corroded seed with dried pulpy layer exposed. Still attached to fragment of sporophyll, *sp*. The snout-like region (split longitudinally) faces the observer. $\times 3$. (V.51592.)

FIG. 28. Same, viewed at right angles to preceding with snout, *s*, to left, remains of rachis (sporophyll) *sp*., to right. $\times 3$.

FIG. 29. Detached somewhat crushed larger seed, probably this species. $\times 3$ approx. (16.)

FIG. 30. Pyriform smooth detached seed, attachment side. Split at apex indicates micropyle and embryo vesicle. $\times 2.2$. (17.)

FIG. 31. Apex of the same, showing split. $\times 2.2$.

FIG. 32. Another inflated smoothly rounded seed. *v*, apical vesicle slightly asymmetrically placed. $\times 2.2$. (18.)

FIG. 33. Apex of same showing two small apertures closely adjacent (?twinned vesicles). $\times 2.2$.

FIG. 34. Small pointed seed with remains of outer integument. Shows lateral vesicle as circular scar, *v*, connected with base by a furrow (incipient split) which separates the snout, *sn*, from the main body of the seed. $\times 6.5$. (V.51591.)

FIG. 35. Same, opposite side, showing large attachment facet, *f*, occupying more than half the length adhering to a fragment of longitudinally striate rachis on right. $\times 6.5$.

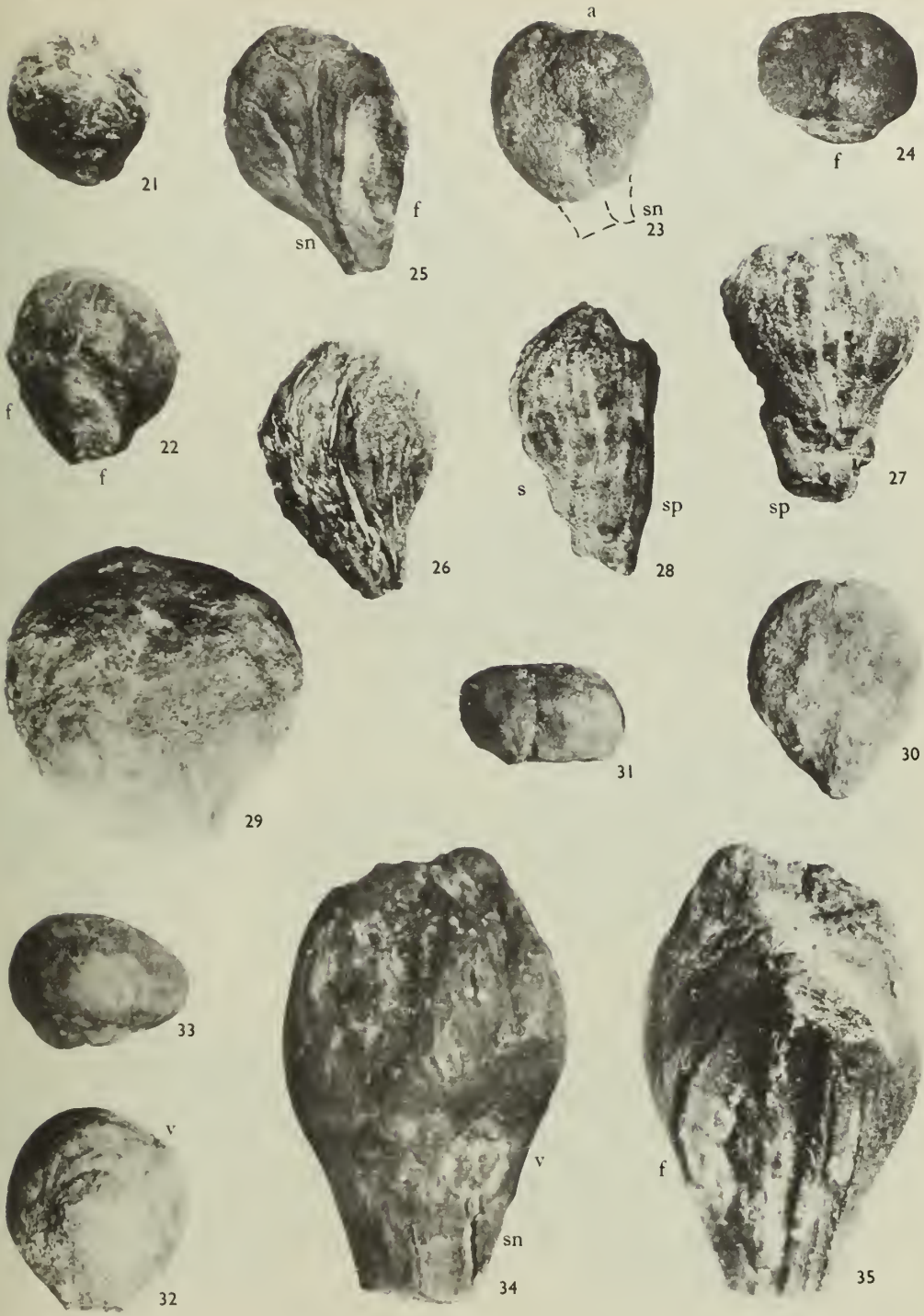


PLATE 4

Behuninia joannei gen. et sp. n.

FIG. 36. Large pair of seeds with clearly marked longitudinal fibres on right seed, upper surface. Left seed much damaged. $\times 2.2$. (12.)

FIG. 37. Pair of seeds, *s*, attached to sporophyll, *sp*, lower surface showing rachis flanked by projecting lamina with thickened rim, *r*. $\times 3$ approx. (19.)

FIG. 38. Pair of much battered seeds, lower surface, showing subcircular areas of unknown nature but possibly due to inflation of small tracts between sunk nerves. $\times 3$ approx. (11.)

FIGS. 39, 40. Opposite sides of a pair of unequally developed seeds, *s*, Fig. 39, lower surface, showing typical fibres with anastomosing transverse branches. A bud-like structure is seen at *b*; *r*, is rachis. Fig. 40 shows the upper surface. $\times 2$ approx. (13.)

FIGS. 41, 42. Smooth obovoid detached seed with external fibres clearly displayed. Fig. 41 attachment side with facet, *f*. Fig. 42, opposite side, fibres converging to subapical micropyle. $\times 2.5$. (6.)

FIG. 43. Another, similarly preserved. Margin of attachment facet seen at *f*. Micropyle indicated by convergence of fibres on right. $\times 3$. (15.)

? Family *Cycadales*. Genus ?

FIG. 44. Part of one limb of a dorsiventral scale with remains of a seed, *s*, (broken distally) embedded in a crenature of the limb with claw-like edges, *cl*. Broken end of limb at *b*. (cf. text-fig. 3). $\times 1.5$. (21.)

FIG. 45. Opposite side of same showing marginal rim of seed. Lettering as in fig. 44. $\times 2.2$.

FIG. 46. Same, looking onto section of fractured seed, *s*. Shallower edge of crenature which holds seed and more inflated rimmed side of seed are on the right. *cl*, claws; outer claw of crenature at base of figure, inner at top. $\times 1.5$.

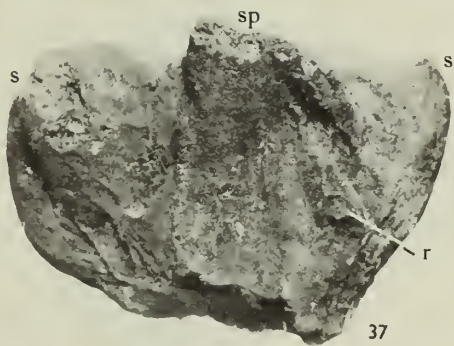
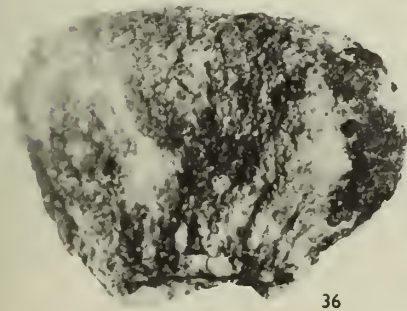
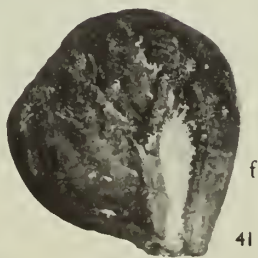
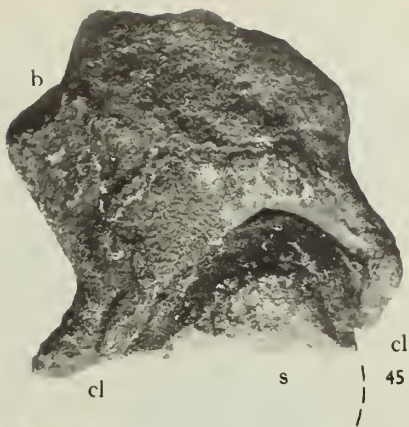
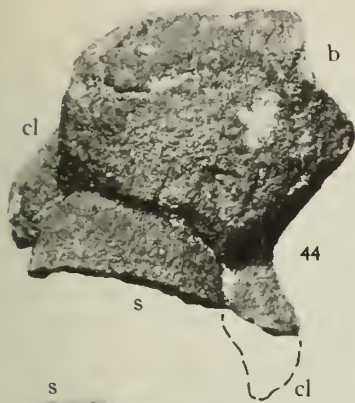


PLATE 5

Jensensispermum redmondi gen. et sp. n.

FIGS. 47-49. Syntype. A seed apparently referable to this species with most of the integument so rarely preserved. Fig. 47, side view, micropylar end at *m* tending to split transversely into two jaw-like portions, *uj*, *lj*. *l* a cast of a lateral cavity. The jaw labelled *uj* is here depicted as representing the upper side of the seed but it is possible that the discovery of an infructescence may show that this position must be reversed. *a*, attachment area. Fig. 48 shows the "lower" jaw. Lettering as above. Fig. 49 shows the "upper" jaw. Some small depressions on the right are nearer to the micropylar end than in fig. 48. All the above $\times 6.5$. (22.)

FIG. 50. Syntype. A typical abraded seed which has lost its integument showing elongate form. Looking onto "upper" (chalaza) side. Hilum to left as this seed contracts towards it. The two depressions on the left separated by a short ridge may be due to the lateral cavities. $\times 6.5$. (24.)

FIG. 51. Syntype. Side view of an abraded seed with fibrous pulpy layers of integument exposed. *m*, micropyle, splitting into two jaws has started here. *r*, marks the limits of the hilar-chalazal region, *ch*, on the left (dark in figure), the endosperm lying to the right. *h*, approximate position of hilum. $\times 6.5$. (23.)

FIG. 52. Seed, looking onto micropyle, abraded so that fibrous pulpy layers of the integument *f*, are exposed. Transverse split at *m* overlies the micropyle. $\times 6.5$. (V.51599.)

FIG. 53. Syntype. Seed looking onto micropyle. Endosperm still partly covered by pulpy fibres but sufficiently abraded for embryo scar, *m*, to be exposed with fibres diverging from it. $\times 6.5$. (30.)

FIG. 54. Another, side view, showing diagonally the junction of chalaza, *ch*, and endosperm, *a*. End of embryo vesicle seen at *e*. *h*, hilar area. Rugose surface of chalaza clearly seen. $\times 6.5$. (V.51601.)

FIG. 55. Syntype. Seed, side, looking onto junction (vertical line) of endosperm (left) and chalazal region (right). Flattened area at top is hilar area in profile. $\times 6.5$. (25.)

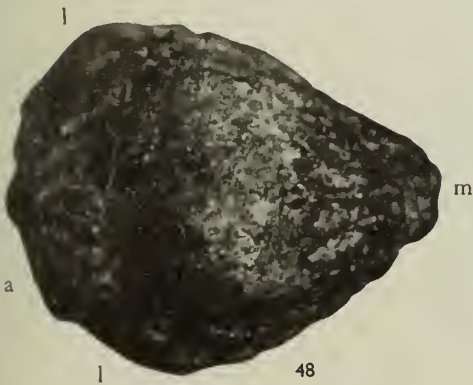
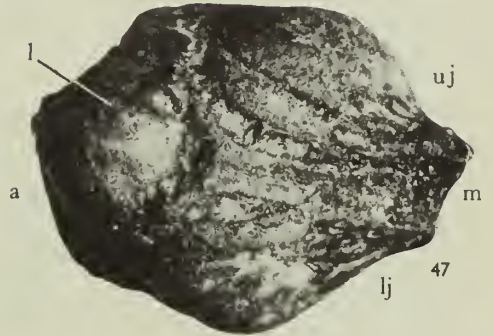
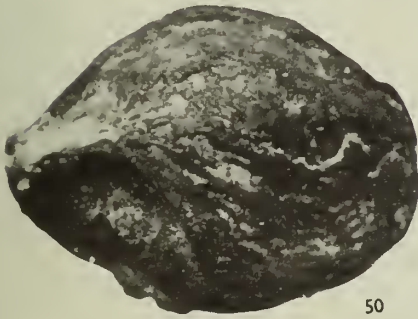
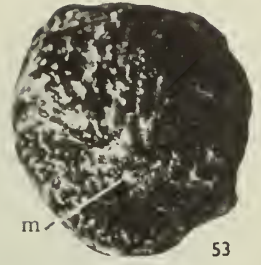
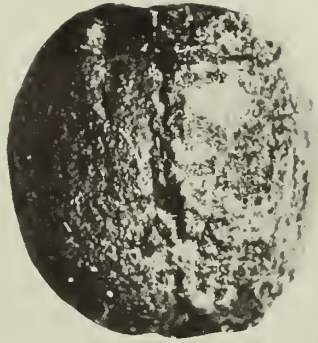
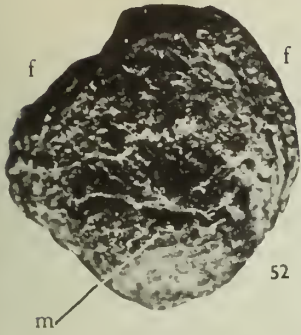


PLATE 6

Jensensispermum redmondi gen. et sp. n.

FIG. 56. Same seed as in Plate 5, fig. 55. Looking onto endosperm showing conspicuous navel-like embryo vesicle at centre. $\times 2.5$. (25.)

FIG. 57. Same. $\times 6.5$.

FIG. 58. Same, looking onto large hilar scar superficially resembling that of some Sapindaceae. Apertures for fibres to chalazal area are seen at centre of scar and at top right near junction of chalaza, *ch*, and endosperm, *a*, with the hilar scar. $\times 6.5$.

FIG. 59. Same, opposite end to hilum. Endosperm, *a*, occupies left half of figure, chalazal region, *ch*, occupies right half. Junction, *j*, between the two lies to left of longitudinal median diameter. $\times 6.5$.

FIG. 60. Same, looking at chalazal region (i.e. opposite side to that in figs. 56, 57). Scar near base, due to wrinkles near edge of chalaza, does not appear to represent a seed organ. Flattening at top of figure indicates hilar scar in profile. $\times 6.5$.

FIG. 61. Another seed with typically exposed endosperm and embryo vesicle (at centre). $\times 2.5$. (V.51603.)

FIG. 62. Seed, side, endosperm to left sharply separated by diagonal junction from chalazal region to right. Cast of hilar cavity at apex with projection, *f*, connected with funicle fibres. $\times 6.5$. (V.51600.)

FIG. 63. Same, looking onto cast of hilar cavity which, as lighted, appears four-sided. The projection at the top of the scar is triangular in outline with two facets separated by a verticle angle. Endosperm, *a*, occupies the lower part of the figure. Junction with chalazal region above is seen at *j*. $\times 6.5$.

FIG. 64. Syntype. Seed, side, hilar area, *h*, seen at apex is hollowed. *ch*, puckered retracted chalazal region distinctly separated by diagonal rounded margin from contracted endosperm. Embryo vesicle at point, *m* (cf. Text-fig. 17). $\times 6.5$. (26.)

FIGS. 65, 66. Seed. Fig. 65 looking onto endosperm. Central embryo scar obscure in figure, clear in specimen. *h*, edge of hilar area; *ch*, edge of chalaza. Fig. 66 looking onto fibrous chalaza region; *h*, hilar area. $\times 6.5$. (32.)

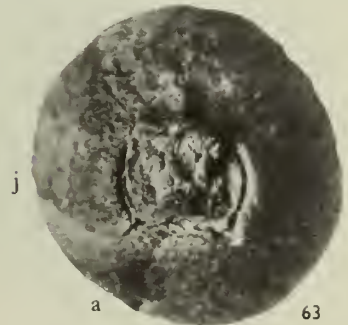
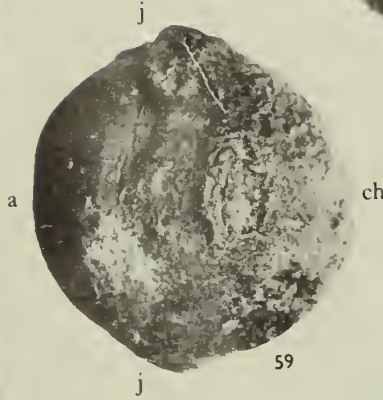
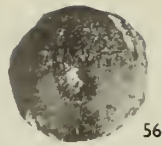


PLATE 7

Jensensispermum redmondi gen. et sp. n.

FIG. 67. Seed, Endosperm on left. Puckering of endosperm, due to contraction, is seen at junction, *j*, with chalaza. Embryo vesicle a deeply sunk pit seen obscurely on left (almost in profile). Chalazal area somewhat abraded. Remains of hilar region form a projection at top of figure. $\times 6.5$. (V.51604.)

FIG. 68. Syntype. Seed, looking onto abraded chalazal region, the circular junction with endosperm is clearly shown as are fine (white) nerves which radiate over the endosperm from this junction. Worn hilar region lies between *h*, *h*. $\times 6.5$. (29.)

FIG. 69. Seed with chalazal region, *ch*, largely abraded, exposing rounded extent of the endosperm (above). The specimen shows nerves diverging from chalaza over endosperm but these are obscure in the figure. *h*, position of hilum. $\times 6.5$. (V.51602.)

FIG. 70. Syntype. Endosperm of a seed seen from much abraded chalaza side. Hollowed rim of the endosperm surrounds the small central fibrous chalazal remains. Embryo vesicle is at centre of rounded endosperm surface on which specimen lies. Hilar scar (abraded) lay towards top of figure. $\times 6.5$. (27.)

FIG. 71. Seed looking onto endosperm with conspicuous embryo vesicle, *e*. Ridge across the endosperm below it is due to faulty preservation. $\times 6.5$. (31.)

FIG. 72. Seed in Plate 5, fig. 54. looking onto endosperm with plug of embryo vesicle slightly extruded (centre). Hilar scar, *h*, seen in profile. Elsewhere margin of seed formed by edges of chalaza. $\times 6.5$. (V.51601.)

FIG. 73. Seed, side. Vertical junction, *j*, of endosperm (left) with chalazal region clear. Flattened cast of hilar cavity at *h*. Slight depression, centre left, position of embryo vesicle. Longitudinally rugose surface of chalazal region due to sunk fibres clearly seen. $\times 6.5$. (V.51605.)

FIG. 74. Syntype. Seed tilted to show surface of cast of shallow hilar cavity. Chalazal region below with well preserved surface showing longitudinal fibres diverging from hilar area and arising beneath cast of hilar cavity. Limits of endosperm at *a*, *a*. $\times 6.5$. (28.)

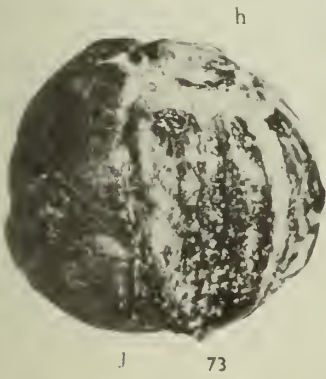


PLATE 8

Sequoia sp.

FIG. 75. Cone cast looking onto narrower diameter. Shows spirally arranged lozenge-shaped scales broader than high with transverse ridge or furrow. Scales outlined by darker calcite ridges. Short stalk seen at base. $\times 3$ approx. (38.)

FIG. 76. Same, turned to left through 90° , looking onto broader diameter. $\times 2.6$.

FIG. 77. Larger cone, scales represented by featureless light grey calcite outlined by darker ridges between them. Tilted slightly so that part of apex is visible in shadow. A line of fracture runs transversely from *c* to *c*. $\times 2$. (39.)

FIG. 78. Same, looking onto transversely fractured surface (lower portion) showing obscure outlines of the flat seeds in dark calcite contrasting with lighter calcite beyond and between them. Surface of cone seen in fig. 77 is towards base of figure. $\times 2.6$.

FIG. 79. Less well preserved cone, side. $\times 2.6$. (V.51617.)

Hillistrobus axelrodi gen. et sp. n.

FIG. 80. Syntype. Small almost perfect cone, extreme tips of most scales slightly imperfect. $\times 2.5$. (40.)

FIG. 81. Syntype. Larger crushed cone. $\times 3$ approx. (41.)

FIGS. 82, 83. Opposite sides of an imperfect cone, lower half missing. Fig. 82 shows elongate scale tips. Fig. 83 shows the opposite side of the cone with scales abraded so that the attenuated tips are worn away. $\times 2.6$. (V.51618.)

FIG. 84. Cone fragment, near base. $\times 2.5$. (45.)

FIG. 85. Syntype. Lower part of more elongate cone showing attenuated scale tips merging below into foliage-like scales. $\times 2.6$. (42.)

FIG. 86. Twig which may have borne a cone at the tip. Leaves may be compared with basal scales in fig. 85. $\times 2.6$. (43.)



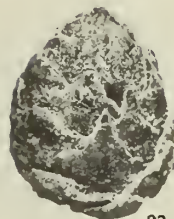
81



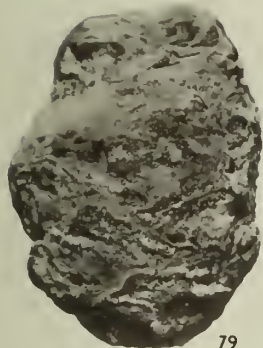
84



83



82



79



86



78



85



80



75



76



77

PLATE 9

Hillistrobus axelrodi gen. et sp. n.

FIG. 87. Lower part of larger cone transversely fractured showing the thin overlapping scales with concave upper and angled lower surface and attenuated margins. $\times 3$. (44.)

Genus ?

FIG. 88. Much abraded cone with scales worn so that apices are gone exposing thickened central part. Possibly this species. $\times 2.6$. (48.)

Genus ?

FIG. 89. Battered cone with small spirally arranged scales. $\times 2.6$. (49.)

Carpolithus provoensis sp. n.

FIG. 90. Holotype. Integument or cupule, side view showing two basal facets near *f*, and truncated apex. $\times 1.9$. (50.)

FIG. 91. Same, opposite side, with furrow at base. $\times 1.5$.

FIG. 92. Same, apex, showing pointed segments, 1 to 5 partially obscured by matrix. $\times 1.6$.

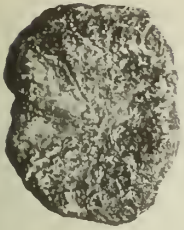
Carpolithus radiatus sp. n.

FIGS. 93-95. Syntype. Seed. Fig. 93, concave apex of peltate radially furrowed integument. Fig. 94, side showing contraction into stalk. Fig. 95, base looking onto broken stalk. $\times 2.2$. (51.)

FIGS. 96-98. Another specimen with sharply angled circumference (abraded). Fig. 96, apex; fig. 97, side; fig. 98, base showing very slender stalk and radial furrows. $\times 2$ approx. (52.)

FIGS. 99-101. Another. Fig. 99, apex; fig. 100, side; fig. 101, base. $\times 2$ approx. (V.51619.)

FIGS. 102-104. Abraded poorly preserved specimen. Fig. 102, apex with outline of horizontal albuminous seed cast. It shows central depression connected by channel with margin. Fig. 103, base, fig. 104, side (stalk broken off short). $\times 2$ approx. (V.51620.)



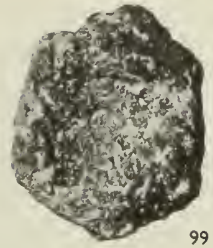
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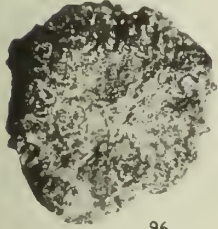
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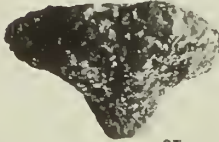
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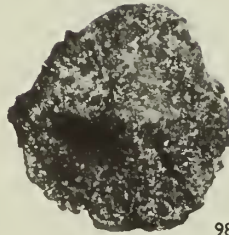
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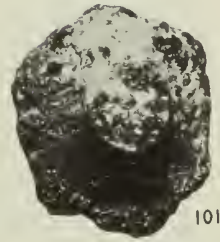
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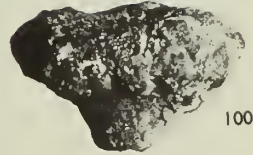
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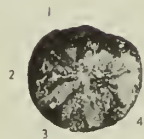


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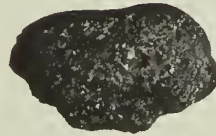
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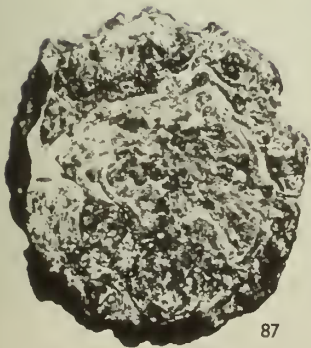
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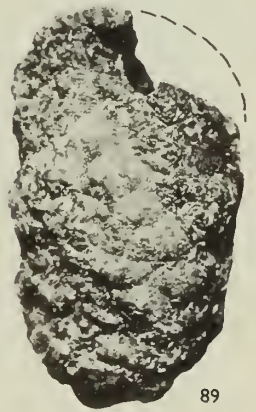
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PLATE 10

Carpolithus radiatus sp. n.

FIGS. 105-107. Syntype. Peltate seed with lateral bud arising from stalk and albuminous seed cast exposed at apex. Fig. 105, apex, showing tip of bud, *b*, and seed cast with central depression connected by a canal with margin of integument. Fig. 106, side view, bud arising on left. Fig. 107, base with thick broken stalk, bud on left. $\times 2$ approx. (53.)

FIGS. 108-110. Seed with much thickened disc-like form. Fig. 108, apex, with indication of central micropyle. Fig. 109, side, showing thickness of disc. Fig. 110, base. $\times 2$ approx. (V.51621.)

FIGS. 111-113. Seed with stalk and part of integument broken away. Fig. 111, apex; seed cast (= endosperm) exposed at *s*. White spot at centre indicates micropyle. Fig. 112, side, seed cast exposed below equator. Fig. 113, opposite side, tilted to bring concave apex with micropyle (white) into view. Seed cast exposed in shadow below *s*, *s*. $\times 2$ approx. (V.51622.)

FIGS. 114-116. A dorsiventrally thick specimen. Fig. 114, apex. The tangential cut due to embedded stick suggests fleshy texture of endosperm. Fig. 115, side. Fig. 116, base. $\times 2$ approx. (54.)

FIG. 117. Seed, apex, possibly with embryo scar (central white spot). $\times 2$ approx. (55.)

FIG. 118. Base of a seed showing stalk with radial structure. $\times 2$ approx. (56.)

FIGS. 119, 120. Syntype. Fig. 119, apex of seed with small central scar indicating micropyle (embryo vesicle?). Fig. 120, base from which stalk and integument have been abraded showing rugose surface of chalazal region (cf. *Jensensispermum*). *h*, position of hilum. $\times 2$ approx. (58.)

FIGS. 121, 122. Syntype. Twinned seeds. Fig. 121, apex; *s*, *s*, line of separation between two closely adpressed seeds. Fig. 122, base, lettering as above. $\times 2$ approx. (59.)

FIGS. 123, 124. A peltate disc which has been fractured longitudinally before fossilization. Fig. 123, side, exterior. Fig. 124, fractured surface showing fibrous axis with pair of fibre strands. $\times 2$ approx. (57.)

FIGS. 125, 126. Another longitudinally fractured disc with median fibres. Fig. 125, exterior; fig. 126, fractured surface on which a median canal is seen. $\times 2$ approx. (V.51623.)

FIGS. 127, 128. Syntype. Peltate disc with marked apical mucro fractured as in preceding. Fig. 127, exterior; fig. 128, fractured surface with axis terminating in mucro flanked by shallow radial cavities. $\times 3$ approx. (60.)

FIGS. 129, 130. Club-shaped head (immature seed or barren shoot tip). Fig. 129, apex with diverging fibres. Fig. 130, side. $\times 3$ approx. (61.)

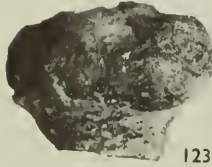
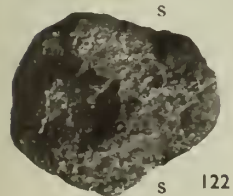
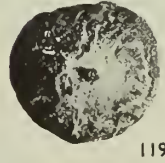
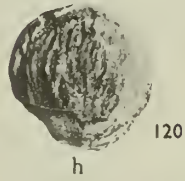
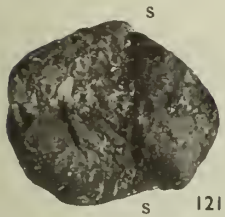
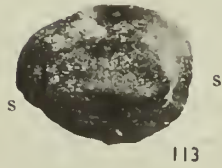
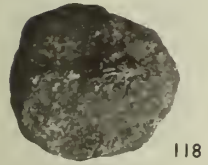
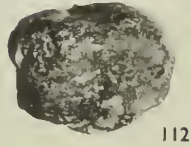
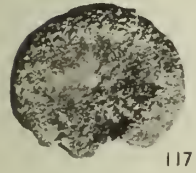
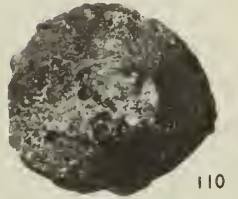
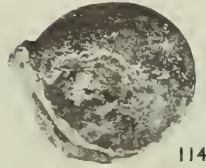
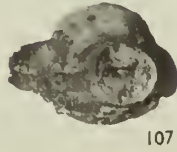
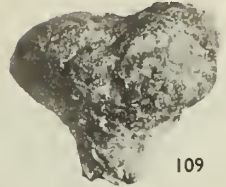
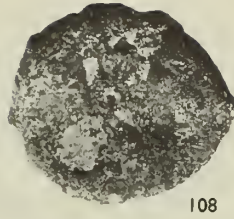
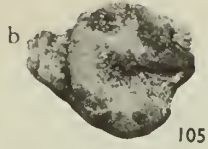


PLATE 11

Carpolithus spp.

FIG. 131. Seed enclosed in a cupule which bears four unequal rounded segments above, of which two adjacent ones are small. Apical view. $\times 1$ approx. (66.)

FIG. 132. Same, base abraded so that the seed is exposed through a gap in cupule. $\times 1$ approx.

FIG. 133. Another, apex much flattened, three segments above. Junction of lobes, *j*, obscure in figure clearer in specimen. $\times 1$ approx. (67.)

FIG. 134. Same, base, more or less uncrushed with projecting central attachment. $\times 1$ approx.

FIGS. 135, 136. Opposite sides of a fibrous striate "fruit", broken at one end. $\times 1.5$. (68.)

FIGS. 137, 138. Another, opposite sides, pointed at both ends (both slightly imperfect). $\times 1.5$. (V.51628.)

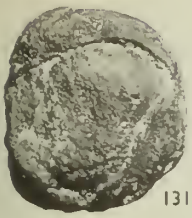
FIGS. 139, 140. Another with expanded base (crushed cupule or sucker-like attachment), opposite sides. $\times 1.6$. (69.)

FIGS. 141, 142. Similar but larger specimen broken at tip; opposite sides. $\times 1.6$. (70.)

FIGS. 143, 144. Another broken at one end, opposite sides. $\times 1.6$. (71.)

FIG. 145. Specimen pointed at both ends. $\times 1.5$. (72.)

FIG. 146. Specimen, nature unknown, presenting a false appearance of a rimmed pod. $\times 1.6$. (75.)



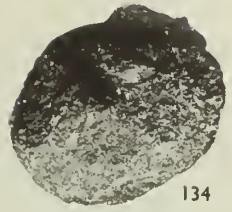
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PLATE 12

FIG. 147. Twinned algal or fungal body showing superficial concentric striae. $\times 1.6$. (76.)

FIGS. 148, 149. Opposite sides of another alga, fungus or tuber. Fig. 149 cut off on right by edge of plate. $\times 1.6$. (77.)

FIGS. 150, 151. Large flattened algal-like object with clearly marked concentric structure and irregular pitting at centre of both surfaces. Opposite sides. $\times 1.6$. (78.)

FIG. 152. Similar body which had been fractured showing crystal-filled cavity without internal structure. Part of specimen cut off by edge of plate on left. $\times 1.6$. (79.)

FIGS. 153, 154. A curved obconical fragment of unknown affinity which appears to have been split longitudinally, the other half being missing. Fibrous radial structure is seen on the exterior (fig. 153). Tendency to shred and weather along the fibrous lines may be seen. Fig. 154 shows the plane of fracture. In both figures the curved convex surface is seen at the apex. $\times 1.6$. (80.)

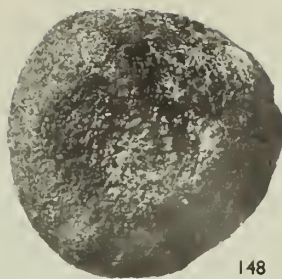
FIG. 155. A detached thorn (unknown affinity). The point, *p*, is down curved. The broad elliptical base with slightly convex surface is seen on left. Its limits at the top of the figure are indicated by *b*, and at the base of the figure are clearly outlined against the shadow. $\times 1.6$. (81.)

FIG. 156. Subglobular body with the exterior splitting into petal-like segments. Possibly fungoid. $\times 1.6$. (82.)

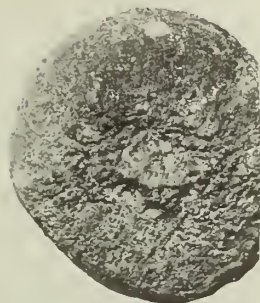
FIG. 157. Object bearing misleading resemblance to a flattened subcircular pod. $\times 1.6$. (83.)



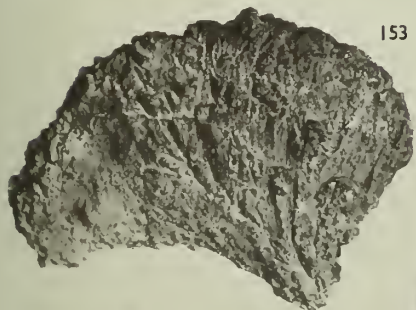
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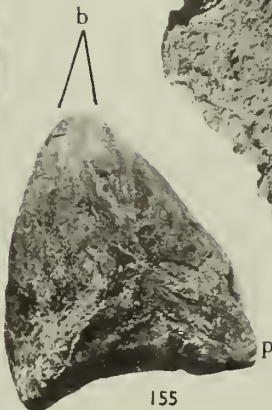
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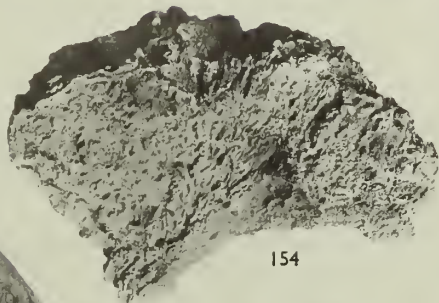
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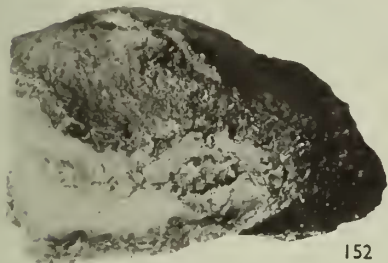
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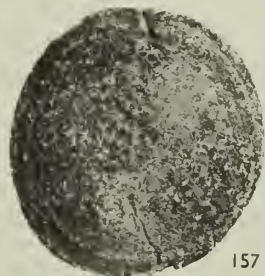
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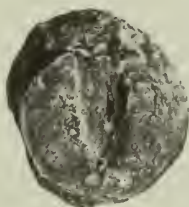
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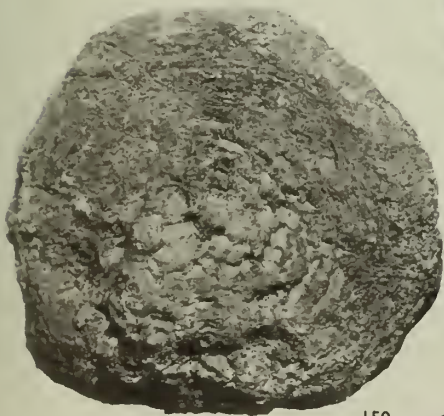
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